California Vocational Agriculture Curriculum Guidelines Instructional Unit

SURVEYING

TABLE OF CONTENTS

SURVEYING

Unit Goals

The goal of this unit is to assist the student in developing his abilities to correctly and accurately use (and care for) surveying equipment and keep a field notebook.

Unit Performance Objectives

Upon completion of this unit, the student will be able to:

1. List the uses of surveying.
2. Take land measurements.
3. Set up and keep a field notebook.
4. Identify the Builders, Engineers, and Turret levels.
5. Identify and use a "direct reading" and "postiive reading" rod with an "Engineer scale" and "Architect scale."
6. Set up an instrument and read a level rod.
7. Make field adjustments plus calculate and determine the difference in elevation between two or more points.
8. Understand subdivision of land.

Teaching Outline

I. Uses of Surveying

A. Uses on the farm

1. Leveling land
2. Laying out buildings
3. Laying out irrigation ditches
4. Setting up building foundations
5. Determining property lines

B. Uses at home

1. Laying out buildings
2. Setting up building foundations and patios
3. Laying out walkways and sidewalks
4. Laying out mow strips
5. Laying out sprinkler systems

C. Uses in construction

1. Laying out buildings
2. Laying out walkways and sidewalks
3. Laying out roads
4. Setting up building foundations
5. Determining property lines
6. Laying out bridges
7. Land grading

D. Uses in forestry

1. Determining elevations
2. Laying out logging roads
3. Watershed management and dam construction

SUGGESTED LEARNING ACTIVITIES	SUGGESTED RESOURCE MATERIAL
1. As an introduction to surveying, have class discussion on: A. The many uses of surveying; B. Items which have been surveyed around their homes or farms. C. The various fields which make use of surveying.	1a. Class members, speakers, from different fields which require surveying. 1b. Use of the level: Setting up the Instrument, V.E.P. Filmstrip and manual from 1-6, Cal-Poly, SLO.

4. Determining property line

5. Determining slopes

6. Determining angles

7. Preparing maps

II. Taking Land Measurements

A. Pacing

1. Pacing involves determining distance by multiplying your pace in feet times the number of paces traveled

2. The length of the human pace varies with the individual, with the rate of speed and the terrain

3. Pacing is indispensible in timber cruising, and in land surveying it may be a very valuable supplement to the more accurate methods

4. Pacing is the least accurate method of the measuring

5. To determine individual paces--see TM 1

B. Chaining

1. Chaining is the process of measuring with a steel tape and pins and consists of two people, the head and the rear chainsman.

2. Chaining is more accurate than pacing

3. The original tool for measuring distance in the woods was the Gunter's Chain. It is 66 feet long and is composed of 100 links of wire, each 7.92 inches long

4. The engineer's chain is a steel tape (chain) 100 feet long and the end foot is divided into 100 parts per foot (some are divided into tenths of a foot.

5. The architect chain is a steel tape (chain) 100 feet long with the end foot divided into inches

6. The steel pins used to mark various intervals in chaining a distance are called Chaining Pins. A set consists of 11 chaining pins

7. Wooden or steel poles used in aligining the chain in long distances are called Range Poles and are usually red and white in color

SUGGESTED LEARNING ACTIVITIES	SUGGESTED RESOURCE MATERIAL
1. Demonstrate proper method of pacing.	1. Forestry Handbook, R.D. Forbes, Ronald Press.
2. Assign students to: A. Determine their individual pace; B. Pace off a predetermined distance and convert to feet and inches. C. Determine acreage of field.	2. Elementary Plane Surveying, Davis. McGraw-Hill T.M.I; Determining pace and acreage.
3. Demonstrate chaining and pinning to students and have students measure a given line.	3. TM-2, Use of the tape.

8. Chains can be used to find 90° angles and in laying out shapes such as squares, rectangles, and triangles

9. See TM-2 for use of the chain and TM 3, 4, 5, 6 for laying out (TM-3 for laying out right angle; TM-4 for laying out rectangle; TM-5 for erecting a right angle or perpendicular with tape or string; TM-6 for area of plane figures)

III. Setting Up and Keeping a Field Notebook

A. Keeping field notes

1. Field notes taken by the surveyor should contain a complete record of all measurements made during the day's work on the survey, with a simple sketch-map indicating location

2. Care should be taken in lettering the field notes

3. The left side of the double page should contain at the top center, the type of exercise attempted. Below this, the information obtained during the survey and all the calculations (TM-7)

4. The right side of the double page should contain, in the upper right hand corner, the page number. On the first line, upper left hand corner, should be the date, below this, the weather and temperature. In the right hand corner, below the page number, should be the crew member's names. Below the temperature on the left side of the page should be a list of the equipment used, location of the survey, and a map of the area surveyed. The direction "north" should be indicated by the map (TM-7)

IV. Types of Levels

A. The level is a device for establishing a horizontal line

1. Engineers

a. Used for work of ordinary accuracy
b. For reading long distances

2. Turret

a. Least expensive
b. Least accurate
c. Good for home simple leveling

3. Builders (dumpy) level

a. Used in simple construction
b. For surveying short distances

B. Parts of the level (See TM-8)

SUGGESTED LEARNING ACTIVITIES	SUGGESTED RESOURCE MATERIAL
1. Have students lay out a right angle with 3-4-5.	1. TM-3, Laying out a right angle, using 3-4-5 method.
2. Have students lay out a rectangle.	2. TM-4, Laying out a rectangle with a chain.
3. Have students erect a right angle with a chain.	3. TM-5, Erect a right angle with a chain; TM-6, Area for plane figures.
4. Have students set up a field notebook.	4. TM-7, Setting up a field notebook.
5. Have students enter material from pacing exercise.	5. TM-1, Determining pace and acreage.
6. Have students identify three levels.	6. Use of the level: Setting up the instrument, V.E.P. Filmstrip and manual. Frame 7. Cal Poly, SLO.
7. Have students identify the parts of the builder's level.	7a. TM-8, Identification of builder's level.
	7b. Use of level; Setting up the instrument, V.E.P. Filmstrip and manual, Frame 11. Cal Poly, SLO.
	7c. Principles of Surveying, C.A. Herubin, Reston Publishing Co., Reston, Virginia.

V. Types of Rods

A. The scale used with the level is called a rod

1. Rods vary in length and width

2. Rods are read through the instrument by the instrument man, so they are called the "self-reading" rods. Self reading rods are of two basic types, "direct reading" and positive reading rods

a. Positive reading - read from the bottom up because the lowest numbers are at the bottom
b. Direct reading - read from the top down because the lowest numbers are on the top
c. Types of positive reading rods are:

1) Philadelphia
2) San Francisco
3) Chicago
4) Metric
5) Architect

d A type of direct reading rod is the elevation or "linker" rod

B. Rods have either metric, engineers, or architect scales

C. Use of the rod:

1. Reading

a. Red numbers = feet
b. Black numbers = tenths of feet engineers
c. Black numbers = inches with architect
d. Black and white spaces = hundreths of feet and are read where color changes

2. See TM-9 and 9-A for instruction and diagram on the reading rod

VI. Setting Up an Instrument

A. Safety

1. Protect instrument from impact

2. Place the lens and tripod caps in the instrument box while the instrument is in use

3. Do not run while carrying the instrument

4. Leave box closed and store while not in use

SUGGESTED LEARNING ACTIVITIES	SUGGESTED RESOURCE MATERIAL
1a. Demonstrate proper method of reading a rod.	1. Use of the level: Reading the rod. V.E.P. Filmstrip and manual, Frame 32-38. Cal Poly, SLO.
b. Assign each student a different point on the scale and have them determine the correct reading.	
2. Have students identify types of rods and "positive" and "direct" reading" rods.	2. Use of the level: Reading the rod. V.E.P. Filmstrip and manual, Frame 18-22. Cal Poly, SLO.

5. Protect lens from direct sun rays

6. Cross fences by spreading tri-pod legs and place on far side of fence before crossing

7. Do not jam leveling screws

8. Do not touch lens with finger, clean only with soft cloth

B. Tri-pod

1. Used to hold instrument

2. To set up tri-pod see TM 10

C. Mount and level instrument

1. Connect instrument to tri-pod (TM-11)

2. Level instrument (TM-11)

D. Focus the instrument
Turn focus screw (TM 8)

VII. Differential Leveling

A. Differential leveling is one of the most useful surveying skills since you can determine the elevation of points that are some distance apart

B. Differential leveling is based upon the idea that you can find the elevation of one point if you know the elevation of another

C. Used as a standard throughout the United States in conservation practices

D. Definitions associated with differential leveling:

1. Differential leveling - difference in elevation on horizontal line

2. Bench mark (BM) - a permanently established reference point, the elevation of which is assumed or accurately known

3. Backsight (BS) - A level rod reading on one point of a known elevation

4. Foresight (FS) - The level rod reading on a turning point or some other point of unknown elevation

5. Height of instrument (HI) - the elevation of the line of sight of a surveying instrument

SUGGESTED LEARNING ACTIVITIES	SUGGESTED RESOURCE MATERIAL
1. Demonstrate the following activities to the students:	1. "Use of the level: Setting up the instruments," V.E.P. Filmstrips and manual, Cal-Poly SLO.
a) The proper way to handle the instrument.	
b) The proper method of setting up and adjusting the tri-pod.	b. Frame 13-15 of filmstrip, TM-10.
c) How to mount and level the instrument.	c. Frame 17-30 of filmstrip, TM-11 and TM-11A.
d) How to focus the instrument.	d. Frame 32-39 of filmstrip.
2. Divide class into a group of four and have the students set up and focus the instrument.	2. Use of the level; Setting up the instrument. V.E.P. Filmstrip, and manual, TM-10, 11, TM-11A.
3. Demonstrate on board how to determine elevations by differential leveling.	3. "An exercise in differential leveling." V.E.P. filmstrip and manual, Frame 2-8, Cal Poly, SLO.
4. Have students differential level a closed course and enter data in field notebook.	4. TM-13-13A.

6. Turning point (TP) - A point whose elevation is determined by subtracting the foresight from the height of instrument in leveling

E. Formulas used with differential leveling

1. HI = elevation + backsight (HI = Elev. + B.S.)

2. Elevation = height of instrument - foresight (Elev. = HI-FS)

F. See TM 12 and 12-A for example on differential leveling

G. See TM 13 and 13-A for sample problem on differential leveling

H. See TM 7 and 7-A for method of entering data from TM 13 and 13-A into field notebook

VIII. Subdivision of Land

A. The basic system in laying out a plot of land is based on:

1. Meridians running North and South

2. Base lines running East and West

3. A Township

a. Composed of 36 sections
b. 6 miles square

4. Boundaries of land as located from survey marker called Bench marks

B. The basic legal description of land is based on Section, Township and Range (TM-14)

1. Sections (640 acres) are divided into lots of less than 40 acres

2. 40 acre piece is described as 1/4 of 1/4 of a given section number

SUGGESTED LEARNING ACTIVITIES	SUGGESTED RESOURCE MATERIAL
1. Assign students to find legal description on a piece of land on a county map.	1a. County Assessor's Office. 1b. Rural real estate office.

STUDENT EVALUATION

1. List 7 uses of surveying.

   a.

   b.

   c.

   d.

   e.

   f.

   g.

   h.

2. Identify three types of levels:

   a.

   b.

   c.

3. Identify three types of rods:

   a.

   b.

   c.

4. Have students set up and level an instrument.

5. Have students differential level and enter figures in Field Book for TM-13A. Construct course on school sight.

Determining Pace and Acreage

A. Pace the length of a 100 foot tape or a predetermined distance 3 times. Now take the average number of paces and divide the number into 100 feet. This gives the number of feet per pace.

B. Lay off a field of known distance, 1,000 feet by 400 feet, and have the students pace off the field and convert their pace to feet and tenths of feet, then determine the acreage in the field.

C. Sample calculations, if pace is 40/100 feet:

$$\frac{100 \text{ ft.}}{40} = 2.5 \text{ feet/pace or step}$$

2.5 ft./pace x 400 paces = 1,000 feet

2.5 ft./pace x 160 paces = 400 feet

$$\frac{1{,}000 \text{ ft.} \times 400 \text{ ft.}}{43{,}560 \text{ sq. ft./acre}} = \frac{400{,}000 \text{ sq. ft.}}{43{,}560 \text{ sq. ft./acre}} = 9.18 \text{ acres}$$

Use of the Chain

A. Keep the tape straight. If kinked pull the end back through the looped part.

B. Unroll slowly and carefully.

C. At the initial point, marked by a transit stake, the Rear Chainman (R.C.) holds one pin and the Head Chainman (H.C.) begins with 10 pins on his ring.

D. R.C. lines up H.C. with point being measured.

E. R.C. holds the chain on mark and yells "mark" when the 100 foot end of the tape comes up with the point of beginning.

F. H.C. pulls chain tight - "10 lbs.," sticks the pin into the ground at 90° angle across chain and yells "mark-mark."

G. The H.C. moves to next measure (100 ft.) and repeats.

H. R.C. picks up pins. At the finish the number of pins he has is the number of 100 feet measured. Example: R.C. holds 7 pins; this means he has traveled 700 feet.

I. When the end of the line is reached, the H.C. halts and the R.C. goes up to the last pin set. The tape is adjusted so that an even foot mark is opposite the pin, and the terminus falls within the end foot length. The number of tenths and hundreths which extend beyond the terminus is subtracted from the number the R.C. reads, to obtain the measured fractional distance. For example: the H.C. observes 0.30 as that part of the tape which extends beyond the terminus, and the R.C. observes his foot mark to be 35 feet. The H.C. then calls out "subtract thirty hundreths" and they both make the subtraction mentally, and check each other on the result, 34.70 feet.

J. If the R.C. holds 7 pins in his hand, not counting the one in the ground, the total distance traveled is 734.70 feet.

K. Wipe the tape with an oily rag.

L. Roll the tape and store.

Laying Out a Right Angle with a Chain Using the 3-4-5 Method

Station:

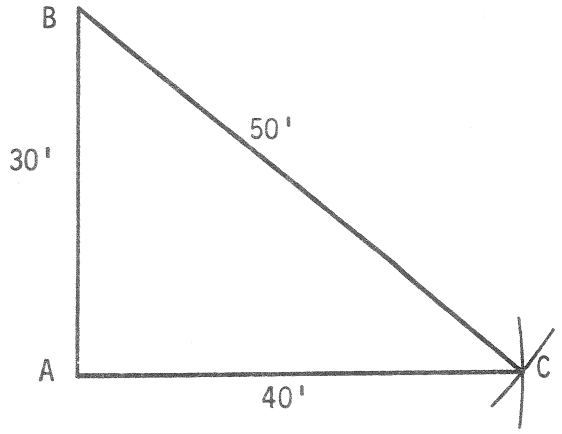
A = Given point

A B = 30 feet on a given line

A C = An arc of 40' approximately 90° to AB

B C = An arc from B of 50' across arc AC

C = Point of interception of arcs AC and BC



Laying Out a Rectangle with a Chain

Station:

A B = Given base line

B = 40' from A

A C = An arc of 30'

B C = An arc of 50' across arc AC

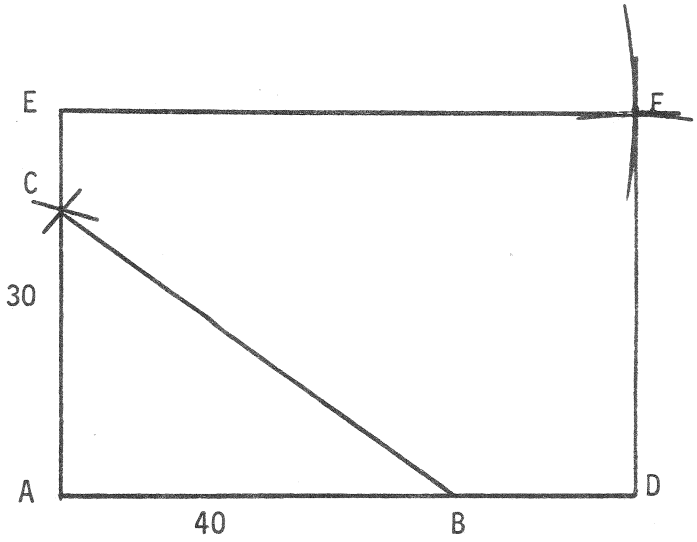
A D = Required distances for sides of building

A E = Required distances for sides of building

E F = An arc of length AD

D F = An arc of length AE across arc EF

F = Point of interception of arcs EF and DF



Area = L x W

TM-4

Erecting a Right Angle with a Cord, Wire Rope or String (or erecting a perpendicular to a line)

Station:

AB = Given base line

C = Given point

AC = Arc of length X

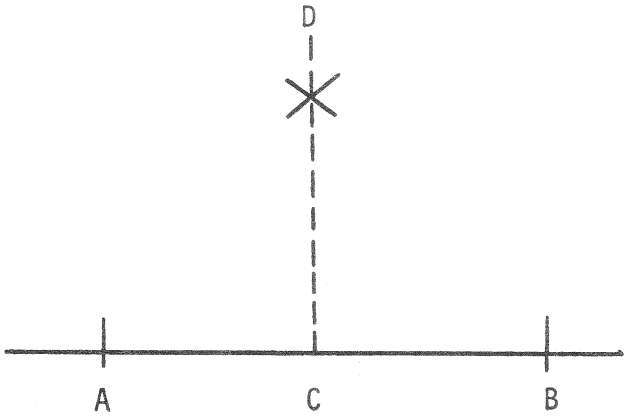
BC = Arc AC

AD = Arc (greater than) arc AC

BD = Arc AD

D = Point of interception of arcs AD and BD

BCD = Right angle = ACD



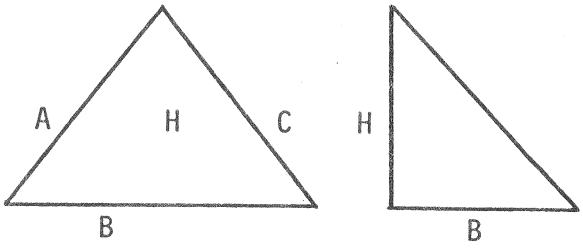
TM-5

AREA FOR PLANE FIGURES

1. Measuring <u>rectangular</u> areas.

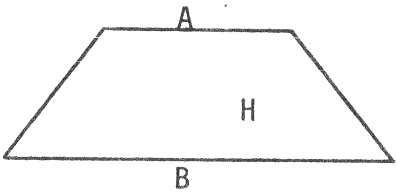
$$\text{Area} = L \times W$$

2. Measuring <u>triangular</u> areas.



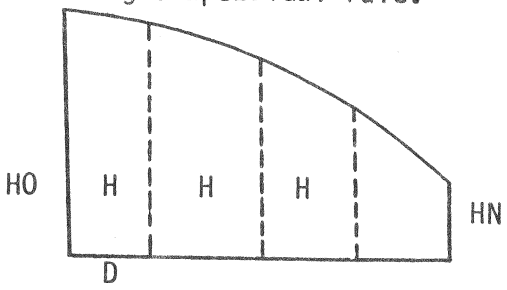
$$\text{Area} = \frac{B \times H}{2}$$

3. Measuring <u>trapezoidal</u> areas.



$$\text{Area} = \frac{(A + B)}{2} \times H$$

4. Area of a figure with a curved boundary, using trapezoidal rule.



$$\text{Area} = D\left(\frac{HO}{2} - H + \frac{HN}{2}\right)$$

5. Determining acreage:

   a. One acre = 43,560 square feet

   b. Acres = $\frac{\text{area (square feet)}}{43{,}560 \text{ sq. ft./acre}}$

SETTING UP A FIELD BOOK

A. Index page

Page	INDEX	Problem
1	Pacing	1
2	Chaining	2
3	Laying out foundation	3

B. Double page showing method used to enter notes. (All calculations should be shown.)

PACING						DATE WEATHER			Page 1		
Sta		Dist							CREW	MEMBERS	
						Equipment					
A-B		160 paces									
B-C		100 paces				Location: NW corner					
						of feed lot					
Pace	= 2.5 feet										
2.5 x 160 = 400 ft.							B	400 paces		C	N
2.5 x 400 = 1000 ft.							160 paces				
400 ft. x 1000 ft. = 9.18 acre											
43,560 sq. ft.							A				

TM-7A

SUGGESTED FIELD NOTE SHEET IF NOTEBOOKS ARE UNAVAILABLE

STA	BS	HI	FS	ELEV.	CALCULATIONS

Problem: _____

_____

_____

Survey Party: _____ _____

_____ _____

Date: _____ Weather: _____

Equipment Used: _____

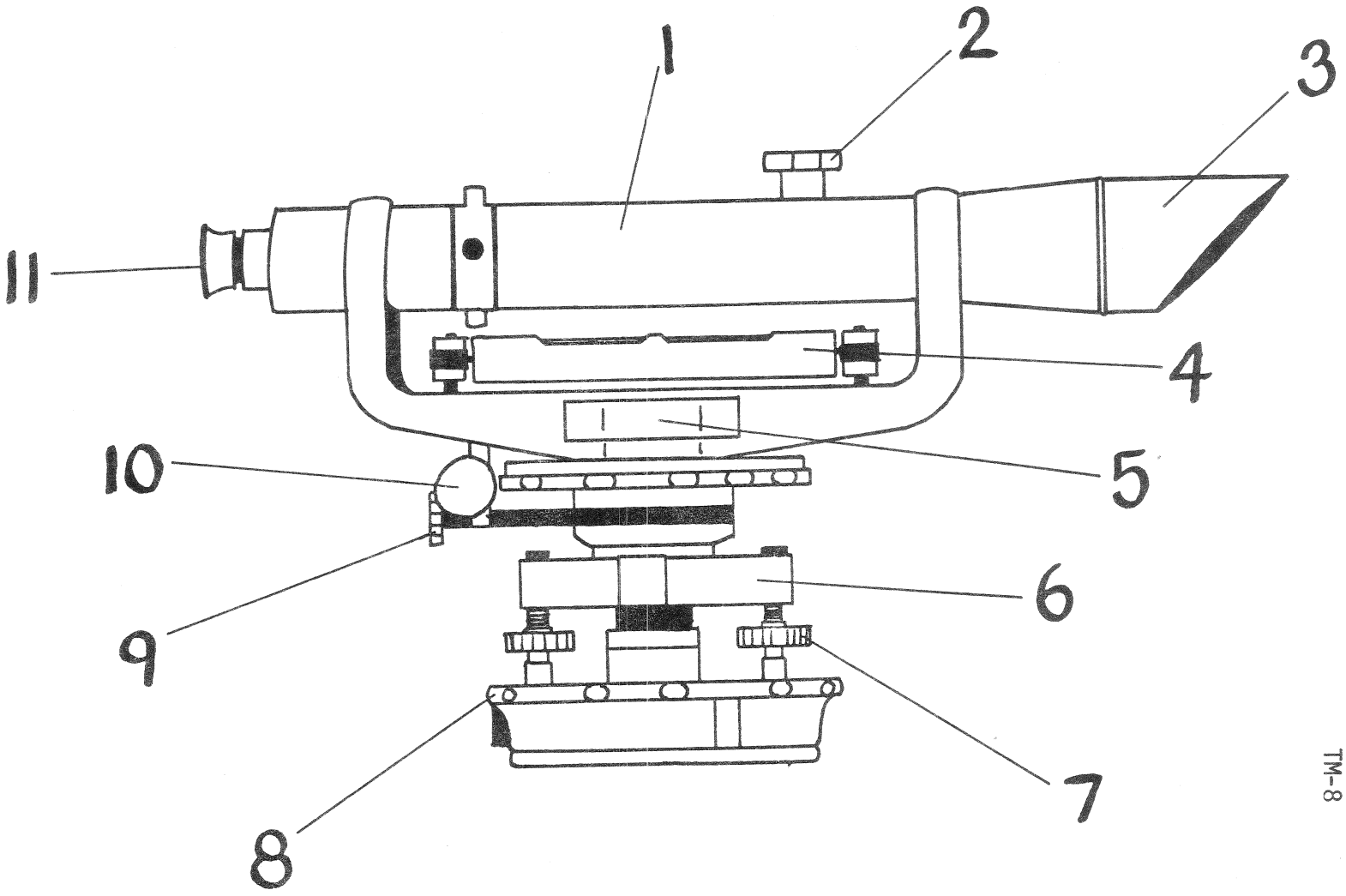
_____

_____

_____

MAP

BUILDERS LEVEL



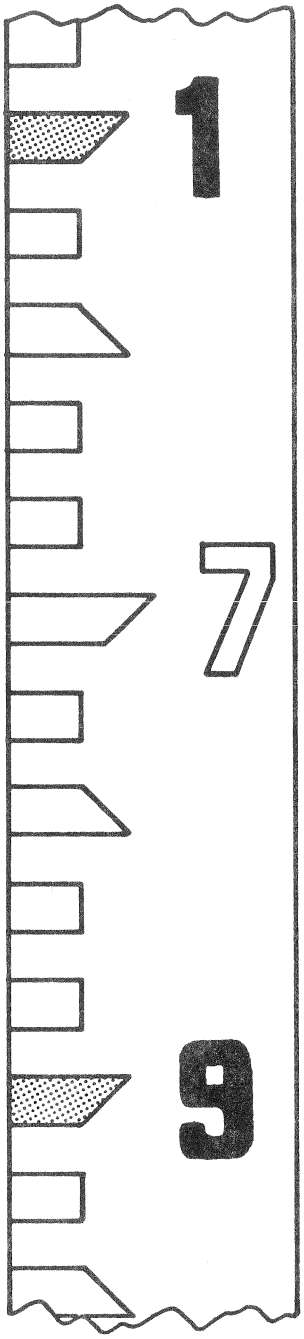
TM-8

BUILDERS LEVEL

1. Telescope barrel
2. Focusing screw
3. Sun shade
4. Bubble tube
5. Level bar
6. Leveling head
7. Leveling screws
8. Plate
9. Clamp
10. Slow motion screw
11. Eye piece

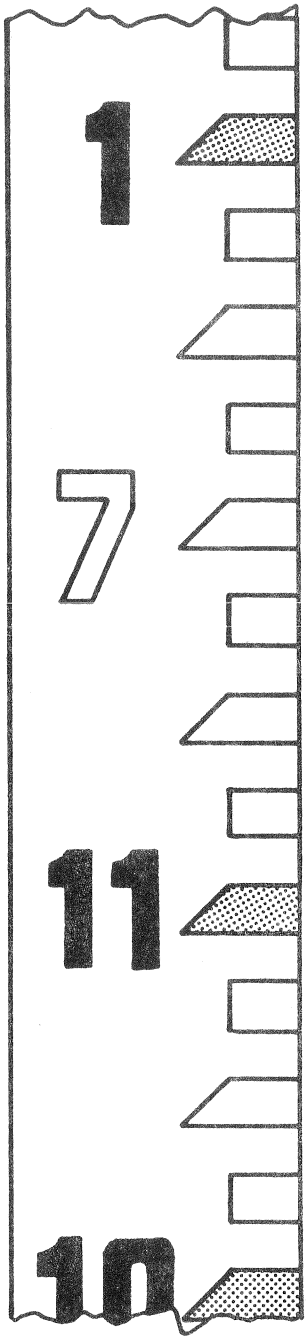
SURVEYING RODS

A.



Feet, 1/10's, 1/100's

B.



Feet, inches, 1/8 inches

READING THE ENGINEERS ROD

figure A

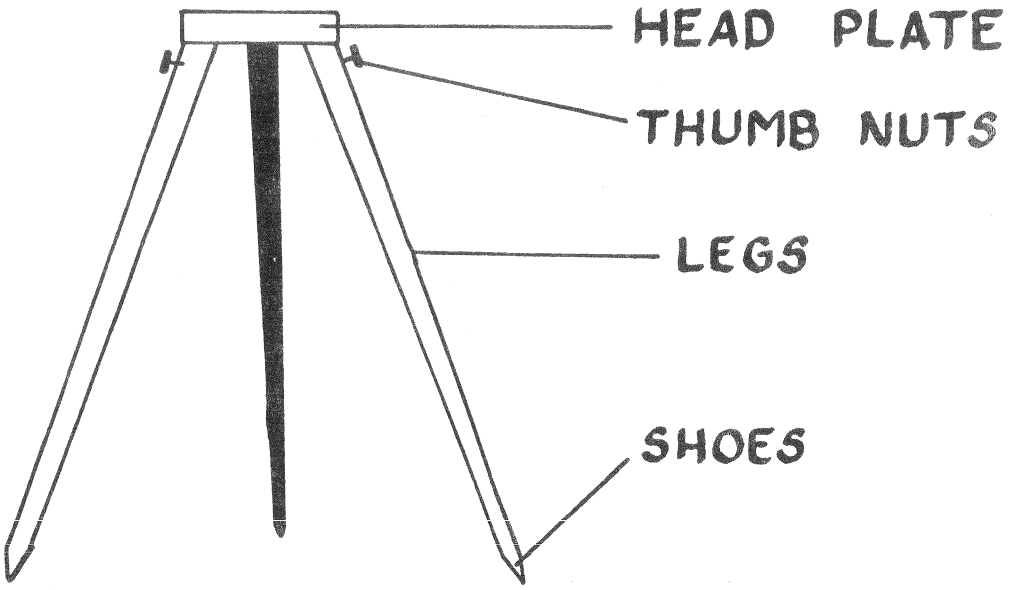
1. The longest markings point directly at the large red numbers that indicate feet. The exact measurement is taken from the flat edge of the marking that forms the sharp point. The small red numbers show the foot reading in case the large red number cannot be seen through the instrument.

2. The numbers in between the large red foot numbers indicate tenths of a foot. Each tenth of a foot is measured at the flat edge of the sharp point just as the foot markings are measured.

3. In between the tenth marks are additional black and white markings, all of them the same width. It takes ten of these black and white markings to make a tenth of a foot. Each of them is one hundreth of a foot wide. If only the black marks are counted they equal 2/100 of a foot.

SETTING UP THE TRIPOD

TM-10



A. Grasp the two legs nearest you and set the leg shoes in the ground about three feet apart.

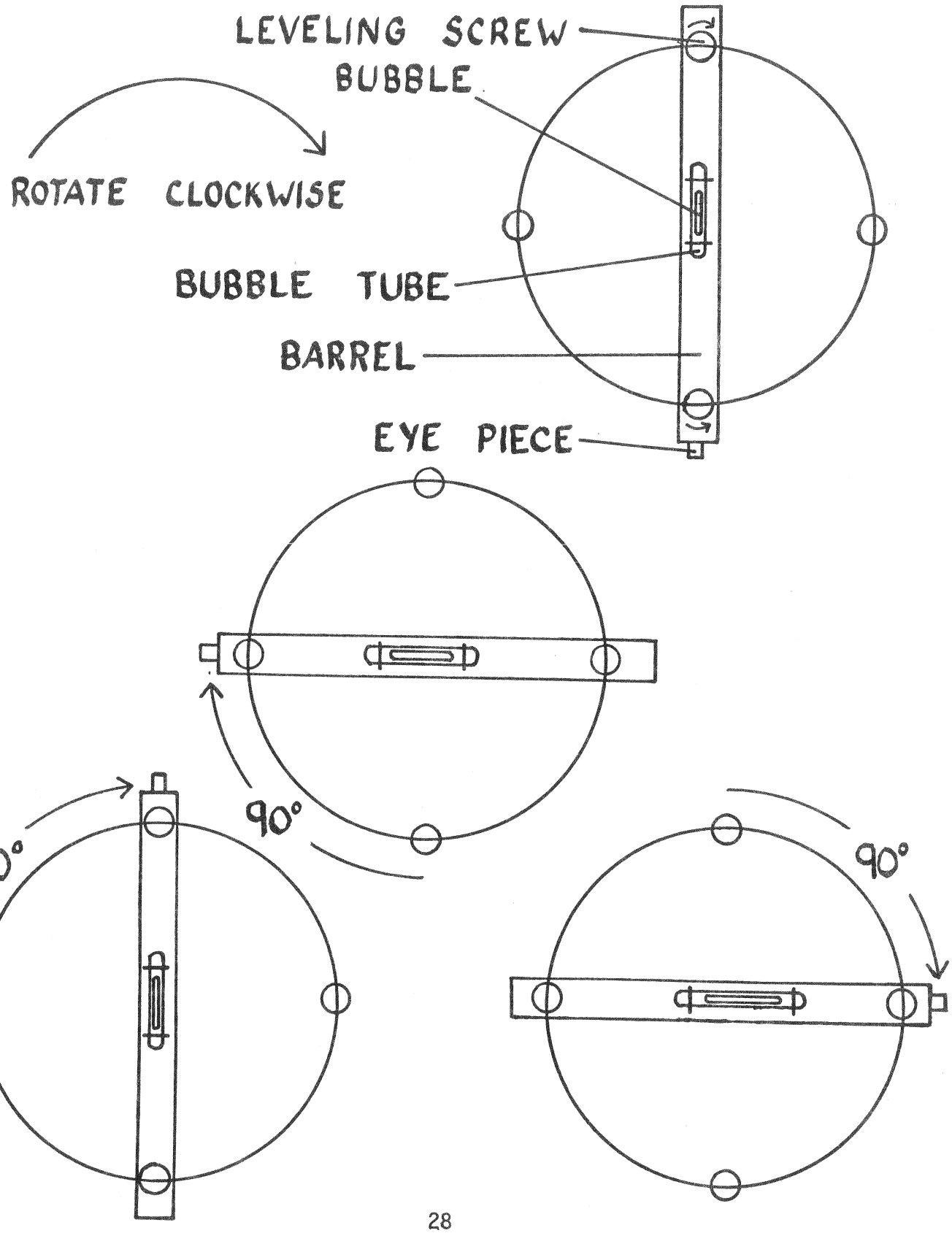
B. Swing the third leg out so as to form an equilateral triangle with the other two. Keep the head plate as level as possible.

C. Tighten the leg thumb nuts to provide rigidity for the instrument.

D. Check the head plate to make sure that it is level. Sight it up against the roofline of a building, this will help determine the horizontal plane.

LEVELING THE INSTRUMENT

TM-11



MOUNTING AND LEVELING THE INSTRUMENT

(To be used with TM-11)

A. Attach the level to the headplate of the tripod by screwing the level down on the headplate.

B. Remove the dust cap from the front lens. The dust cap is left in place whenever the level is not in use in order to protect the lens from dust and scratches. Attach the sun shade to the instrument.

C. The first step is to align the telescope barrel directly over one pair of leveling screws.

D. To bring the bubble to the center, rotate the screws under the barrel, moving the screws in opposite directions. By loosening one screw and tightening the other at the same time you will keep the instrument tight. Move thumbs in same direction (both in or both out).

E. After you have leveled the instrument with the first pair of screws, turn the barrel clockwise through 90 degrees to align it with the other pair of leveling screws. Bring the bubble to the center of the tube in the same manner as described earlier.

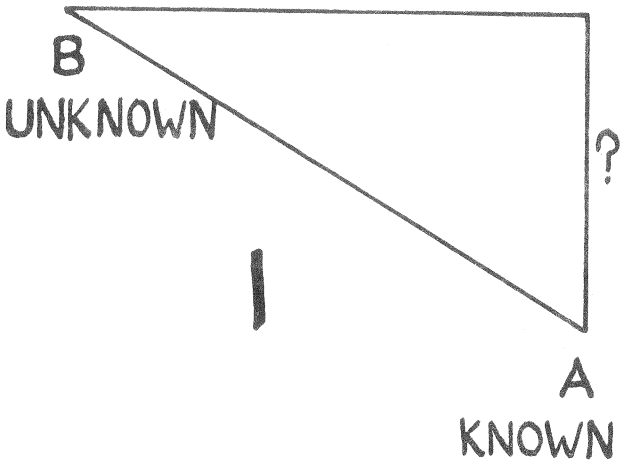
F. Turn the barrel clockwise 90 degrees to bring it parallel with the first pair of leveling screws. It is now facing the opposite direction from its first position. Again center the bubble.

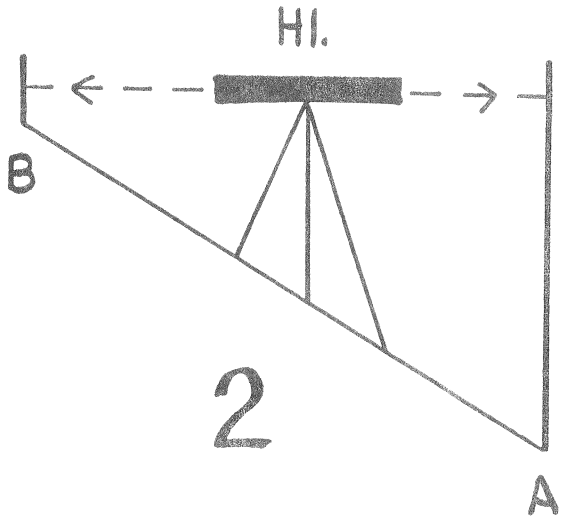
G. Turn the barrel clockwise 90 degrees once again to line up with the second pair of leveling screws (but facing in the opposite direction from that which it faced) and enter the bubble.

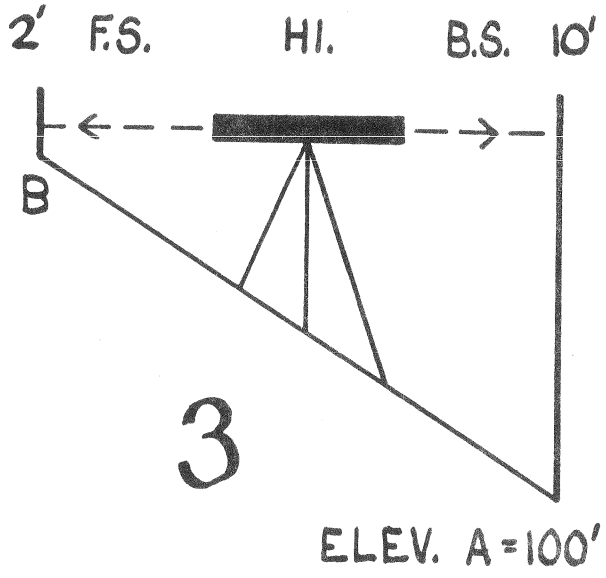
H. Finally bring the telescope barrel back to its original position. The bubble should remain centered. The bubble should stay in the center regardless of the direction is pointed.

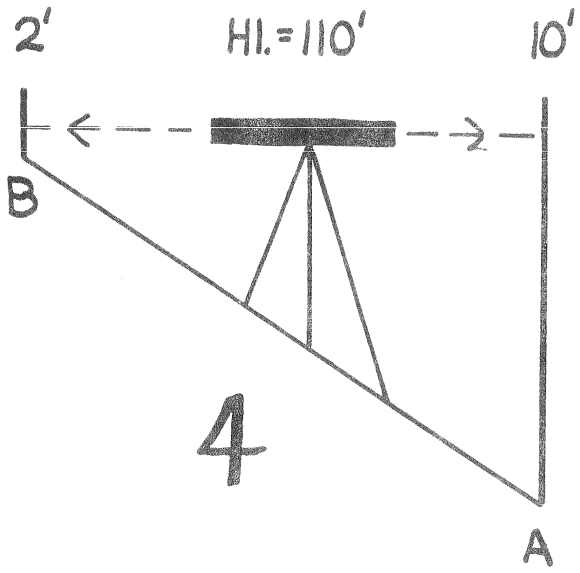
DIFFERENTIAL LEVELING

TM-12









HI. = ELEV. + B.S.

HI. = 100' + 10' = 110'

ELEV. = HI. - F.S.

ELEV. = 110' - 2' = 108'

DIFFERENTIAL LEVELING

(To be used with TM-12)

A. Differential leveling is based on the idea that you can find the elevation of one point if you know the elevation of another.

B. If point A is not exactly known, arbitrarily call it 100 feet. In differential leveling you want to know the difference in elevation and not necessarily the elevation above sea level. If a benchmark is nearby, use the elevation above sea level. From point A you can determine the elevation of point B with a level and a rod.

C. Before the elevation of point B can be determined, the height of the instrument must first be found. This tells how high above point A the instrument is. Add the rod reading to the elevation of point A.

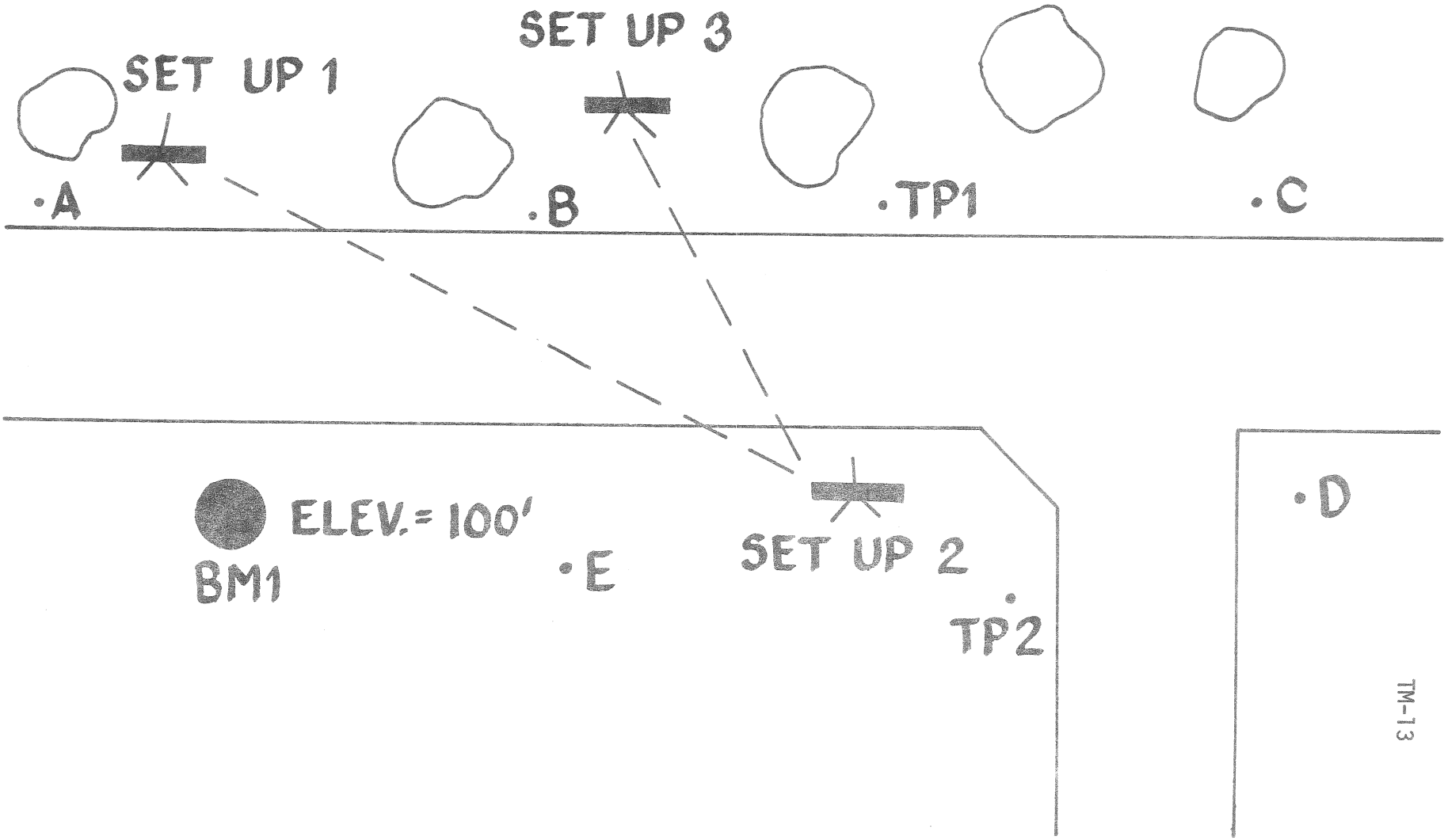
D. To find the elevation of point B, subtract the reading of the rod at point B from the height of the instrument. This gives the elevation of point B.

E. The data from the previous problem should be entered into the left side of the field notebook as follows.

	DIFFERENIAL LEVELING				
STA	BS	HI	FS	ELEV	
A	10	110		100	
B		110	2	108	

DIFFERENTIAL LEVELING PROBLEM

Map showing locations of points for closed differential leveling problem.



TM-13

DIFFERENTIAL LEVELING PROBLEM

(To be used with TM-13)

A. Set up the instrument at approximate location as shown on map.

B. Read rod on BM1 (this is BS on BM1), add this to the known elevation (100') to give HI.

C. Read rod on station A, record this as FS, then subtract this from HI to give the elevation at A.

D. Now read rod on B, same procedure as for A.

E. Read rod on TP1, same procedure as for A and B.

F. Move the instrument to set up site 2, level the instrument, then take a backsight reading on TP1. Record this as a BS in Field Book. Add this to the elevation of TP1 to get the new HI on TP1.

G. Proceed to stations C, D, and TP2 with same procedure as for A, B, and TP1.

H. After obtaining last reading on TP2 and after having determined the elevation on TP2, move the instrument to position and set up 3.

I. After setting instrument, take rod reading on TP2 to obtain a BS reading, add this BS to the elevation of TP2 to get new HI.

J. Read rod at E and BM1, subtract these FS, and check in at BM1, the elevation should be 100'.

SECTION NUMBERING IN A TOWNSHIP

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

<table>
<tr><td>160 Acres
NW 1/4</td><td colspan="2">NE 1/4</td></tr>
<tr><td rowspan="2">SW 1/4</td><td>40 Acres
NW 1/4
SE 1/4</td><td>NE 1/4
SE 1/4</td></tr>
<tr><td>SW 1/4
SE 1/4</td><td>SE 1/4
SE 1/4</td></tr>
</table>

GENERAL REFERENCES

Davis, Elementary Plane Surveying, McGraw-Hill TM-1

R.D. Forbes, Forestry Handbook. Ronald Press Co.

C.A. Herubin, Principles of Surveying. Reston Publishing Company, Reston, Virgin a.

McCormac, Jack C., Surveying. Prentice Hall Inc.