KING FAISAL UNIVERSITY
College Of Engineering

DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING

CEE272: Surveying & GPS

"Lab Manual"

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Major Topics covered and schedule in weeks:

Topic	Week #	Courses Covered
Introduction and Lab safety.	1	CEE 272
Experiment 1: Alignment of a straight line with the bare eye.	2	CEE 272
Experiment 2: Determination of individual's pace length	3	CEE 272
Experiment 3: Horizontal taping over uneven or sloping ground.	4	CEE 272
Experiment 4: Horizontal Control for Mapping by Linear Measurements	5	CEE 272
Experiment 5: Training on Leveling	6	CEE 272
Experiment 6: Differential Leveling	7	CEE 272
Experiment 7: Contouring from Grid	8	CEE 272
Experiment 8: Measurements of horizontal & vertical Angles	9	CEE 272
Experiment 9: Measuring Angles by repetition & horizon closure by repetition	10	CEE 272
Experiment 10: Measurements & calculation of open traverse	11	CEE 272
Experiment 11: Measurements & calculation of closed traverse	12	CEE 272
Experiment 12: Training on Planimeter	13	CEE 272
Experiment 13: Total Station Applications	14	CEE 272
Experiment 14: GPS Applications	15	CEE 272

Specific Outcomes of Instruction (Lab Learning Outcomes):

1. . Ability to explain the specific terminology associated with the discipline of land surveying. (1)
2. Ability to demonstrate knowledge of systems used for land referencing (Latitude/Longitude, State Plane Coordinates) (1)
3. Ability to demonstrate proper use surveying equipment: level, theodolite, Total Station, hand compass and GPS receivers. (3,5)
4. Ability to properly apply techniques for field mapping and area computation. (1)
5. Design and conduct experiments as well as to analyze and interpret data through conducting several field experiments ranging from distance measurements to topographic mapping. (5,6)

Student Outcomes (SO) Addressed by the Lab:

z	Outcome Description General Engineering Student Outcomes	Contribution
1.	an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics	H
2.	an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors	
3.	an ability to communicate effectively with a range of audiences	L
4.	an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts	
5.	an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives	M
6.	an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions	M
7.	an ability to acquire and apply new knowledge as needed, using appropriate learning strategies	

Table of Content

GENERAL POLICIES

1. Attendance:

- Laboratory attendance is mandatory.
- The student will not be allowed to submit a report for an experiment in which he has not participated.
- Students must arrive punctually. If is student is late more than 10 minutes, he will not be allowed to participate in the lab.
- In case of excused absences, make-up laboratories will be considered on a case-by-case basis.

2. Safety:

- Safety should be the primary concern when working in any laboratory. Unsafe behavior will not be tolerated in the lab
- Your laboratory instructor will warn you of potentially dangerous situations which might arise.
- At all times students will conduct themselves in safe manner.
- No eating, drinking, or "horseplay" is permitted in the laboratory.
- Haste causes many accidents. Work deliberately and carefully. Verify your work as you go along. Good planning before coming to the laboratory will promote safety.
- Disciplinary action will be taken against violators.

3. Reports:

- Individual reports are required for every experiment.
- Reports are type written.
- Reports are due 10 days from the day of the experiment.
- Late report will be subjected to a penalty of 15% per day. Late reports will be accepted up to 4 days after the due date. No late report will be accepted after that

4. Use of Surveying Equipment

- Survey equipment are expensive and should always be handled with care.
- If you are not certain about the operation of an instrument, be sure to ask your instructor first
- -Theodolites,levels and total stations should be carried in their cases to field
- Never carry any instruments while it's fixed on a tripod when moving between stations
- Never leave the instrument in the field unattended
- For outside field works the tripod legs should be firmly planted into the ground

FORMATS FOR THE WRITTEN LABORATORY REPORTS:

1- Title Page (Cover Page).
2- Abstract.
3- Introduction.
4- Methodology (Experimental Procedure, Methods and Materials or Equipment).
5- Results and Discussion.
6- Conclusion and Comments.
7- References.
8- Appendences

Experiment 1: Alignment of a straight line with the bare eye.

I. Objective:

The alignment straight of the line means setting out points in the same vertical plane. The line of intersection between any vertical plane and the earth surface is therefore a straight line. The straight line is the line connecting between two points. In some cases you might be required to locate interval points that are aligned with the external points, or locate points that are in the extension of the original ones.

II. Test Standard

III. Theory:

The line of intersection between any vertical plane and the earth surface is therefore a straight line. The straight line is the line connecting between two points.

IV. Apparatus:

1. Eight range poles.
2. Five chaining pins.
3. Two steel tapes 50 and 100 m.

V. Procedure:

Case 1

Setting out new points on the extension of two fixed points AB.

1. Fix two range poles firmly in the ground immediately before or after the pins marking the points A and B in such a way that they lie in the direction of line AB.
2. Hold a range pole at a new point C (Figure 1.1), orient yourself until the three range points at A, B and c coincides. Fix the range pole at point c
3. Move to another new location and repeat step 2. Fix the range pole at point d after making sure that the range poles at A, B, C and D coincides.
4. Continue repeating step 3 until the extension of the line is completed.
5. It is required that every student sets out at least one range pole on the extension of the line AB.
6. Ask the instructor to check your work before starting doing case 2.

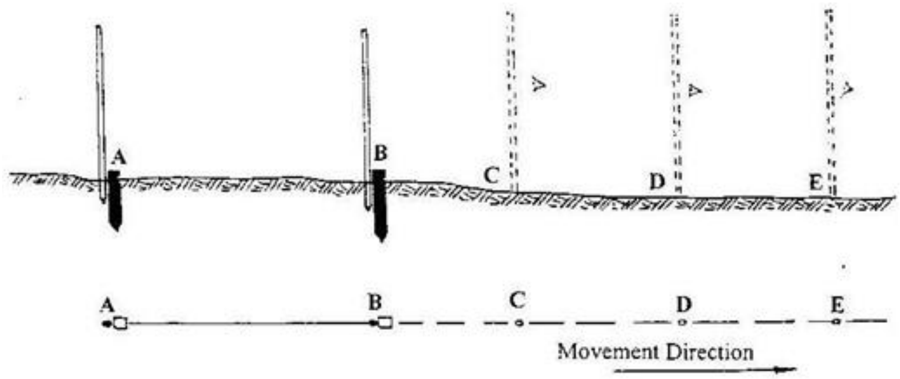


Figure 1.1. Setting out points on the extension of two fixed points.

Case 2
setting out new point on the line between A and B.

1. Fix two range poles at the previously located points A and B in a similar way as mentioned in case one.
2. Stand behind either point, say A, and look towards the other point, in this case B (Figure 1.2).
3. Orient an assistant at point C (near the far point B) to the right or left until the three range poles at A,B and C coincides. Note that the assistance should stand in a perpendicular direction to the direction of line.
4. Instruct the assistant to move to another location. Repeat step 3 until the points, A, B, C, and D coincides.
5. Repeat step 4 until the required number of points is reached.
6. Every student should set out at least one point on the line AB.
7. Ask the instructor to check your work before starting case 3.

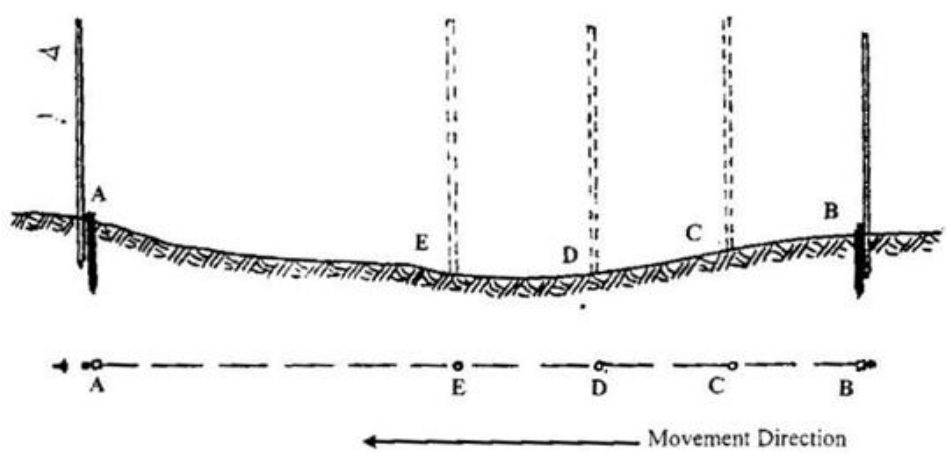


Figure 1.2. Setting out points between two fixed points.

Case 3

Setting out two points on the line between two points A and B separated by high ground.

1. Choose two points C, and D in such a way that C and A can be seen from D, and D and B can be seen from C (Figure 1.3).
2. Two persons (C) and (D) should hold poles at points C and D.
3. Observer (C) orients assistance (D) to the right and left until point D is aligned in line CB..
4. Observer (D), now at new D location, orients assistance (C) to the right and left until point C is aligned in line DA.
5. Step 3 and 4 are then repeated alternatively until the situation is reached, in which the range poles at D, C, and A as well as the range poles at C, D, and B coincide when seen from points D and C respectively. This is an indication that all range poles lie in the same vertical plane that intersects the earth surface in the required line AB.
6. Additional points on the line AB can now be set between points A, C, D, and B using the methods described in case 1 and case 2 above

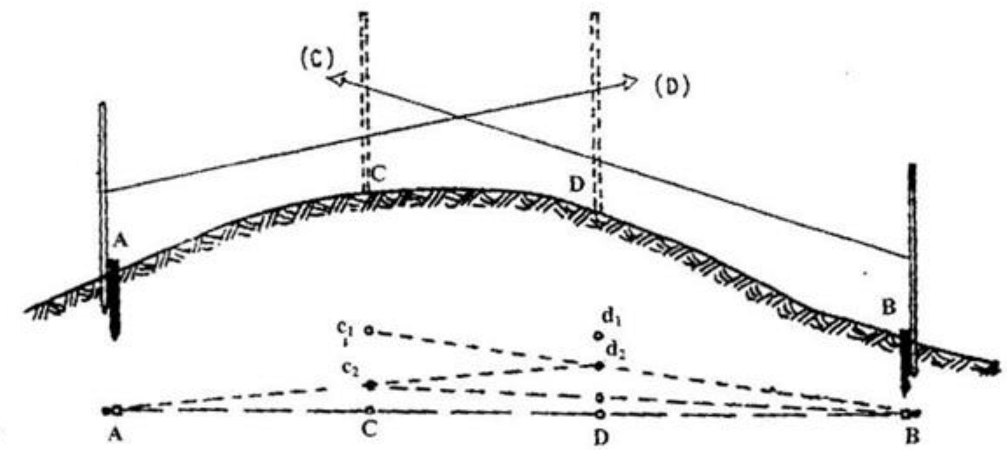


Figure 1.3. Setting out points between two points separated by high ground.

VI. Experimental Work:

1. Setting out new points on the extension of two fixed points AB.
2. Setting out new points on the line between A and B.
3. Setting out two points on the line between two points A and B separated by high ground.

References:

Experiment 2: Determination of individual's pace length

I. Objective:

A person can determine the value of this average pace by counting the paces necessary for him to walk a distance of know length. It is most convenient and satisfactory to take natural steps rather than taking steps of certain lengths.

II. Test Standard

III. Theory:

Pacing is usually used to quickly make approximate measurements or to check measurements made by more precise means.

IV. Apparatus:

1. Eight range poles.
2. Five chaining pins
3. 3. Two steel tapes 50 and 100 m

V. Procedure:

1. Choose a flat stretch of ground and measure a distance of 50 m with a steel tape. Mark the end points.
2. Walk forward over this distance and count your paces. Try to avoid the general tendency to exceed the natural length of pace.
3. Estimate the fraction of the last pace to the nearest one length. Record the number of paces in the field book.
4. Repeat steps 2 and 3 by walking backwards to the point of beginning

VI. Experimental Work:

1. Compute the average length of the natural pace by dividing the total distance walked (in this case 100 m) by the total number of paces.
2. Determine the average number of paces for a distance of 20 m.
3. Record the field data and the calculations as shown in the following example

Table 2.1: Determining average pace length

Track	Student				Remarks
	1	2	3	4	
A - B	80.5	76.8	72.5	77.0	Paces for 50 m
B - A	79.0	75.5	74.2	76.5	Paces for 50 m
SUM	159.5	152.3	146.7	153.5	Paces for 100 m
Sum / 5	31.9	30.5	29.3	30.7	Paces for 20 m

Pace Length	0.63	0.66	0.68	0.65	meters

References:

Experiment 3: Horizontal taping over uneven or sloping ground.

I. Objective:

Measurement of the horizontal distance (AB) located in hilly area using horizontal taping.

II. Test Standard

III. Theory:

If the ground is not horizontal, one or both surveyors must use a plumb bob

IV. Apparatus:

- One steel tape.
- Eleven chaining pins.
- Three range poles.
- Two plumb bobs

V. Procedure:

1. Mark the given points A and B by setting range poles vertically on them.
2. Move in the direction A-B as shown in Figure 3.1 until you reach a position in which you can conveniently hold the tape horizontally. Hang the plumb bob at a round meter reading.
3. Let the rear chainman orient you in line A-B. Insert a chaining pin in the ground to mark the end of the first distance. Record the tape reading: as (d_1).

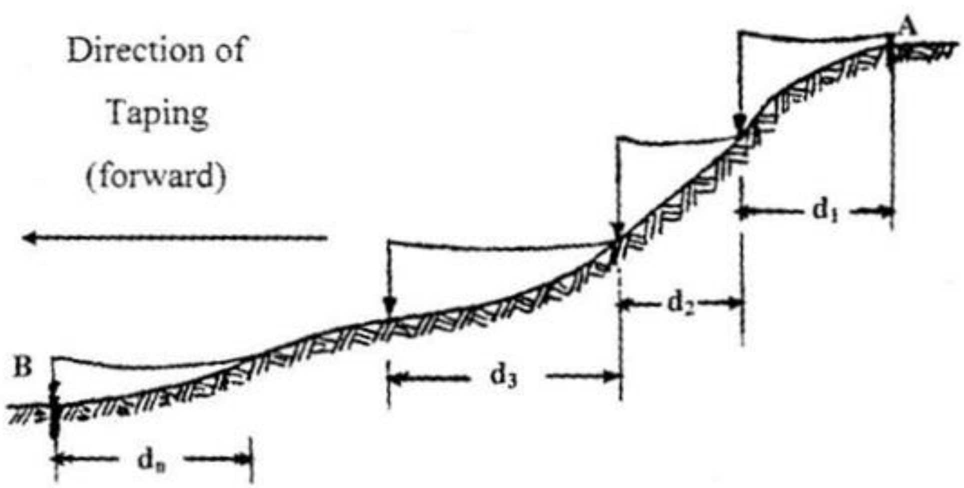


Fig. 3.1

4. Signal to the rear chainman to advance with you in the direction A-B until he reaches the last inserted pin. Choose a location in which you can hold the tape horizontally.

5. Repeat steps 2, 3, and 4 until the last point B is reached. Measure the last distance to the nearest cm. It should be noted here that after you insert a pin in the ground, the rear chainman removes that pin after taking the next reading.
6. Add the measured distances to find, the total distance AB.
   AB= d1 + d2 +d3 +......+ dn …………….. (1)

7. Repeat measuring the distance backwards from point B to point A in the same manner as in steps “2 to 5” (Figure 3.2). Add the distances to get:

BA=d’1 +d’2 +d’3 +......+d’m ……………. (2)

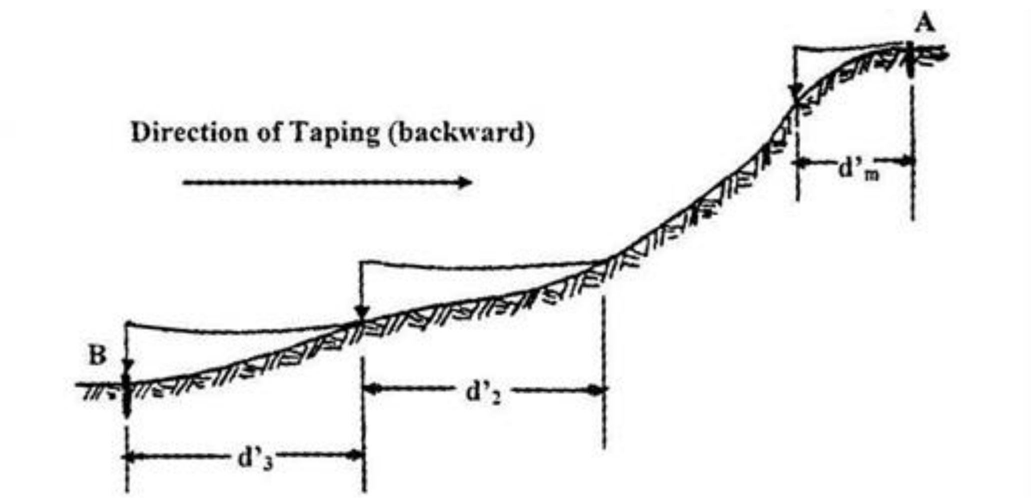


Fig. 3.2

VI. Experimental Work:

1. Calculate the horizontal distance AB as the average of both measurements (AB and BA).
2. Calculate the relative accuracy of the measurements using the following equation:

$$\frac{AB - BA}{AB} = \frac{1}{X} = \text{Relative Accuracy} \quad (3)$$

Example:

Table 3.1: Determining horizontal distance over sloping ground.

Forward Measurements (m)		Backward Measurements (m)	
d_1	15.00	d_1	18.00
d_2	12.00	d_2	10.00
d_3	6.00	d_3	15.00
.		.	
.		.	
.		.	
d_n	19.37	d_m	13.39
118.37		118.39	

Horizontal distance AB = 0.5 (118.37 + 118.39) = 118.38
Relative accuracy = [(118.37 – 118.39)/118.37] = 1/X
Relative accuracy of the measurements = (1/5907) = (1/6000)

Note: X is multiple of 100

References:

Experiment 4: Horizontal Control for Mapping by Linear Measurements

I. Objective:

The purpose of this problem is to train students in traversing using linear measurements only.

II. Test Standard

III. Theory:

By making the necessary linear measurements and triangulation calculation you can draw a map of the area .

IV. Apparatus:

- One steel tape
- One linen tape
- Five range poles.
- Six chaining pins
- One double right angle prism.
- Two plumb bobs.

V. Procedure:

1. Fix four points approximately 40 m apart using pins.
2. Label the points A,B,C and D in counterclockwise direction as shown in Figure 4.1
3. At corner A locate the points a_1 and a_2 on the lines AB and AD respectively. For simplicity take Aa_1=Aa_2= round meter reading. Measure the distance Aa_1
4. , Aa2 and a_1a_2.
5. Repeat step3 at the other points B, C and D.
6. Measure all survey lines AB,BC,CD and DA
7. Submit at the end of the lab a neat sketch showing all your measurements on it

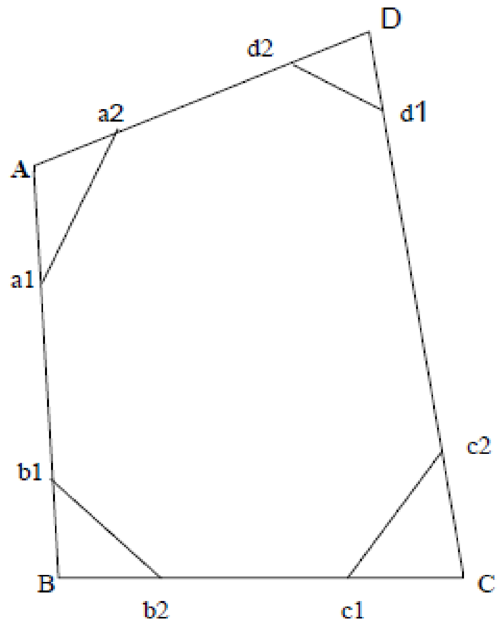


Fig 4.1

VI. Experimental Work:

1. Calculate the internal angles of the traverse ABCDA. For example angle at the corner A in Figure 4.2 can be calculated from $\sin(\alpha/2) = (a_1a_2/2*L)$
2. Add all angles and calculate the angular closing error ώ from ώ= $A^{\wedge}+B^{\wedge}+C^{\wedge}+D^{\wedge} - 360^0$
3. Draw the traverse ABCDA on drawing paper to scale 1:100 using a sharp edge and either protractor or a compass
4. Start by drawing point A, then B,C,D and return back to the point of beginning A.
5. In majority of cases the first point A is reached exactly. Otherwise, another point A' will be obtained as can be seen from figure 4.3
6. The linear closing error is equal to AA' multiplied by the scale of the drawing. The relative error is = $\frac{AA'}{AB+BC+CD+DA} = \frac{1}{X}$
7. Draw a straight line ABCDA' (Figure 4.4) whose length is equal to the summation of AB,BC,CD, and DA'.On this line mark off the distances AB,BC,CD and DA'. If the length of the paper does not permit to draw AA' to the scale of the map, a smaller scale can be used
8. At A' draw a perpendicular to ABCDA' and equal to the closing error AA' as measured from the drawing. Join Aa and draw the per perpendiculars Bb, Cc, Dd to meet the line Aa at points b, c, and d respectively
9. On the plotted traverse draw lines through B,C and D parallel to AA' and set off the distances Bb, Cc and Dd on them as measured from Figure 3.4. Join the lines ab, bc ,cd and da. Shape abcd is the adjusted shape of the traverse

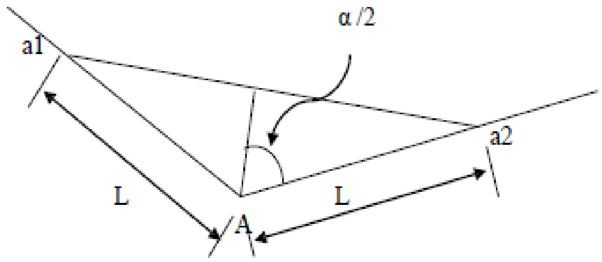


Fig 4.2

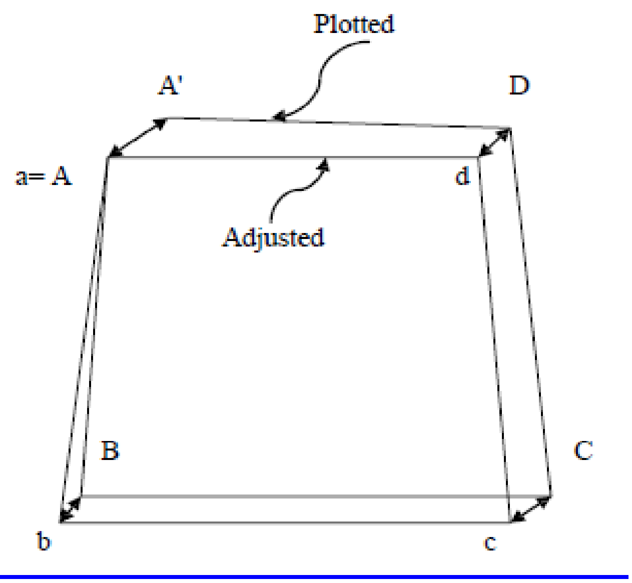


Fig. 4.3

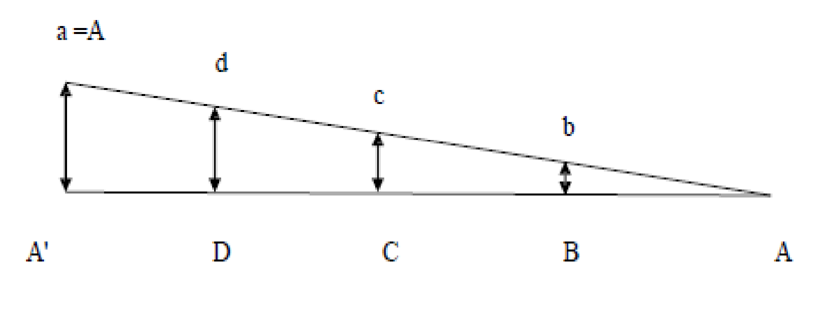


Fig. 4.4

Example:

AB= 47.15 m	Aa_2= Aa_1 = 6.00m	a_1a_2 = 3.84 m
BC = 38.52m	Bb_2= Bb_1 = 5.00m	b_1b_2 = 9.41 m
CD= 42.95 m	Cc_2= Cc_1 = 5.00m	c_1c_2 = 3.47 m
DA =42.24 m	Dd_2= Dd_1 =5.00m	d_1d_2 = 9.46 m

Solution

Point	SIN(1/ 2 ANGLE)	(1/ 2 ANGLE)	ANGLE
A	(3.84/ 2*6) =0.3200	18.66293^o	$37.3259^o = 37^o 20'$
B	(9.41/ 2*5) =0.941	70.22018^o	$140.4404^o = 140^o 26'$
C	(3.47/ 2*5) =0.3470	20.30393^o	$40.6079^o = 40^o 36'$
D	(9.46/ 2*5) =0.9460	71.08491^o	$142.1698^o = 142^o 10'$
		Sum	$360.5440^o = 360^o 33'$
		Sum should be	$360^o 00'$
		Error	$+ 0^o 33'$

References:

Experiment 5: TRAINING ON LEVELING

I. Objective:

Finding the elevation of points above datum by setting up the level many times.

II. Test Standard

III. Theory:

Series leveling is used to find the difference in elevation between two points whenever it is impossible from any instrument station to read the two rods held vertically on them. The reasons can be due to:

- The presence of intervening obstacles.
- Considerable length of the distance between them
- Big difference between their elevations

Usually a leveling is run not only to find the difference in elevation between two points, but also to get the elevations of many other points along the project.
Series leveling is run in steps. Each step starts from a backsight (BS) and ends at a foresight (FS). Points in between (BS and FS) called intermediate points.

IV. Apparatus:

- Leveling instrument
- Two leveling rods.
- Steel Tape.
- Two chaining pins

V. Procedure:

1. Prepare a table in the field notebook for recording the readings according to the method of the instrument height as shown in table. 5.1. Note that all data concerning any point should be recorded on one line in the table.
2. Set and level the instrument at a convenient distance (30m) from the given bench mark(A)
3. Rodman II pace the distance from point (A) Fig 5.1 to the instrument. Pace an equal distance away from the instrument and fix the location of the turning point (B) Note that turning points should be chosen on hard ground, stable objects, concrete surfaces, pavement, firmly driven wooden stakes, iron rods ….etc. In the absence of suitable points use ground plates.
4. Hold rod I vertically on bench mark (A) of the known elevation . Take the rod reading (2.95m) and call it loud. The recorder repeats it loud while he is recording it in the column of back sight(B.S). Record the description of bench mark (A) in the column headed " Remarks" and its elevation above datum (23.67) in the column headed "Elevation"
5. Calculate the height of instrument above datum by adding the BS reading to the given elevation:

   Instrument height= 23.67+2.95= 26.62
6. Hold rod II vertically on point (B), take the reading (3.23m) and record it in the column of foresight (F.S). Calculate its elevation by subtracting the F.S reading from the instrument height.

   Elevation of point B= 26.62- 3.23= 23.39m.

   Record this in the column under "elevation"

7. Signal to Rodman I to move along the leveling route and to hold his rod vertically on other points of interest. Record these readings in the column of intermediate sights (IS).

   Calculate their elevations as done for foresight at(B), by subtracting the IS from instrument height (26.62-3.01=23.61m and 26.62-1.77= 24.85m and so on). Record the elevations in the appropriate column.

8. Now the first step in leveling is finished.

   Instrument- man: moves to a convenient location (station 2) . Set and level the instrument.

   Rodman I: moves along the leveling route. In his way, he should pace the distance between the turning point(B) and station 2.He paces an equal distance and chooses a suitable point (C) as a turning point. He holds the rod vertically on it.

   Rodman II: remains at his place and turns the rod so that the graduation face the instrument.

9. Repeat steps 4,5,6 and 7 until the second step in leveling is finished.
10. Repeat step 8 in which Rodman I remains in his place while Rodman II moves to the next turning point.

Continue the leveling in the same manner until the last point (foresight) is reached

VI. Experimental Work:

1. Calculate the height of instrument above datum by adding the BS reading to the given elevation:
   Instrument height= 23.67+2.95= 26.62
2. Calculate the elevation of point B by subtracting the F.S reading from the instrument height.

   Elevation of point B= 26.62- 3.23= 23.39m.
3. Calculate the elevation of intermediate points by subtracting the F.S reading from the instrument height.

4. Add all backsights (B.S) and all foresights(F.S) and calculate the difference between both sums :
   Σ B.S- Σ F.S = 6.5- 8.74= -2.24m
   Compare this result with the difference in elevation between the last point and the first point
   Elevation of "D" –Elevation of "A" = 21.43- 23.67= -2.24
   <u>Note</u>: Both values must be exactly the same.
5. The mathematical check mentioned in step 12 should be carried out whenever a field book page is completed and at the end of every leveling. It ensures that no errors in addition or subtraction have taken place. This is by no means a check for the correctness of the leveling, as some students may understand it. In normal practice, the leveling is checked by closing it either to a point of known elevation or to the point of beginning by back leveling. This is shown in the next problem.
6. It is preferable to draw a figure similar to Fig 5.1 to understand how the elevations of the points on the earth surface are related to the datum and to the different instrument heights.
   Once the principles of leveling are understood, no figures will be needed

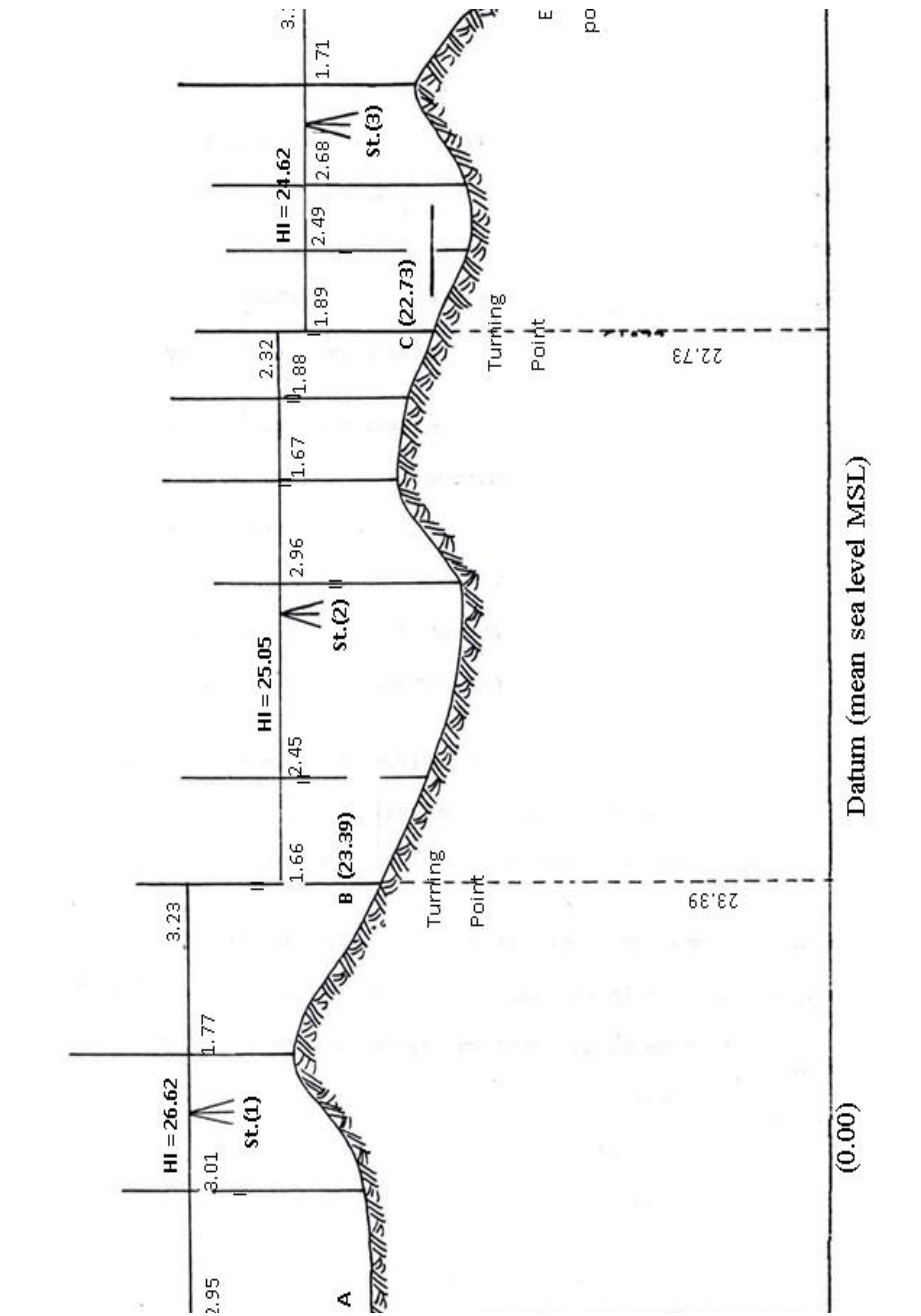
Table 5.1

B.S.(m)	I.S.(m)	F.S.(m)	H.I(m)	Elevation(m)	Remarks
2.95			26.62	23.67	Point A
	3.01			23.61	
	1.77			24.85	
1.66		3.23	25.05	23.39	Point B
	2.45			22.60	
	2.96			22.09	
	1.67			23.38	

	1.88			23.17	
1.89		2.32	24.62	22.73	Point C
	2.49			22.13	
	2.68			21.94	
	1.71			22.91	
		3.19		21.43	Point D
Sum= 6.5		Sum= 8.74			

Σ B.S- Σ F.S = 6.5- 8.74= -2.24m

Elevation of "D" –Elevation of "A" = 21.43- 23.67= -2.24


HI = 26.62
St.(1)
HI = 25.05
St.(2)
HI = 24.62
St.(3)
A
B (23.39)
C (22.73)
Turning Point
Turning Point
23.39
22.73
2.95
3.01
1.77
3.23
1.66
2.45
2.96
1.67
1.88
2.32
1.89
2.49
2.68
1.71
Datum (mean sea level MSL)
(0.00)

Experiment 6: Differential Leveling

I. Objective:

The elevation of a point A above datum by running a leveling circuit from Q to A and back to Q again

II. Test Standard

III. Theory:

1- For the third order leveling , the maximum error of closure(E)should not exceed:

$$E_m = 0.02\sqrt{D_{km}}$$

Where D is the total length of the leveling circuit in Kilometers

If the computed error of closure is greater than allowable, the leveling must be re-run.

$$\text{Elevation Correction} = \frac{\text{Distance from previous point}}{\text{Total travelled distance}} * E$$

IV. Apparatus:

- Leveling instrument
- Two leveling rods.
- Measuring Tape.

V. Procedure:

1- Prepare a leveling table in the field book as shown in table.6.1. Write the elevation of the bench mark in the column headed "Elevation"(assume it to be=49.521 m). Also write number identification of the bench mark in the column headed "Remarks"

2- Set the level at station S_1 (Fig 6.2) and choose the location of the first turning point P_1 so that $QS_1=S_1P_1$.

3- Sight on the rod which is being held vertically on the bench mark at Q. Check the level tube and focus properly before taking the reading. Record this first reading (0.225), which is a backsight in the column headed "B.S."

It is important here to note again, that the instrument man should call the readings in a loud clear tone and the recorder should repeat them while writing. This helps to eliminate mistakes in note keeping.

4- The recorder should calculate the height of instrument (HI= Elevation+ B.S.= 49.521+ 0.225 =49.746) and record it in the column headed "HI".

5- Turn the telescope about the vertical axis and sight on the second rod which is being held vertically on the first turning point P_1. Check the level tube and focus properly. Notice, that if backsight and foresight distance are equal, no focusing is needed. Take the reading (1.995 m) and record it in the second line corresponding to turning point P_1, in the column headed "F.S."

6- The recorder should then calculate the elevation of point P_1(Elevation = HI-FS = 49.746- 1.995= 47.751) and record it in the Elevation column.
7- Record the total distance " Q, S_1, P_1" (46m) in the column headed" Distance"
8- To the instrument man: move to station S_2 and the rodman at Q move to turn point P_2. The rodman should count the paces (or measure the distance) from P_1 to S_2 and chooses point P_2 so that P_1-S_2 = S_2-P_2 approximately.
9- To the rodman at turn point P_1: rotate the rod to face the instrument at new station S_2.
10- The instrument man takes now the backsight (0.445 m) on the rod at P_1. The recorder writes it down in the second line in the "BS" column.

Remember that in addition to the distance, two readings are needed at every turn point. they are in the order backsight and foresight, and since readings belong to the same point, they should be recorded on the same line but in the appropriate columns.

11- Calculate and record the height of instrument at S_2 = 47.751+0.445 = 48.196m
12- Take a foresight reading (2.415m) on turning point P_2 and record it in the "F.S." column.
13- Calculate and record the elevation of P_2 = 48.196 - 2.415 = 45.781
14- Continue the work in the same manner by repeating steps 8,9,10.11,12 and 13 and get the
 Elevation of point A (45.769 m).
15- Check your calculation by adding all backsights(ΣB.S= 1.923m), all foresights(ΣF.S= 5.675m). Then compare the difference between the elevation of point Q and point A with the difference between the summation of backsights and foresights.
16- If the calculation are carried out correctly you will find that the difference s are equal
 (Σ BS- ΣFS = elevation of A- elevation of Q).
17- Remove the instrument and set it again (in the same place if you wish). Start a new leveling from point A as a bench mark of known elevation and run it towards the original point Q. Record the readings and check your calculations. Or shortly, repeat previous steps until point Q is reached.
18- Compare the given elevation (49.521m) of the bench mark with measured one (49.512m). The difference (-0.009m) between both reading is the error of closure.
19- For the third order leveling , the maximum error of closure(E)should not exceed:

$$E_m = 0.02 \sqrt{D_{km}}$$

 Where D is the total length of the leveling circuit in Kilometers
 If the computed error of closure is greater than allowable, the leveling must be re-run.

20- If the error of closure is allowable, adjust the elevations of all of the turning points as well as the elevation of point A by distributing the error of closure on them. The error is distributed according to traveled distance between the traverse points. Therefore, correction to the observed elevation of any point included in the survey is:

$$\text{Elevation Correction} = \frac{\text{Distance from previous point}}{\text{Total travelled distance}} \times E$$

 E =error of closure (0.009m in the example)

For point A in the example

Elevation correction = $\frac{(46+32+26)}{(46+32+26+24+32)}$ x(0.009) = + 0.006 m

Adjusted elevation of A = 45.769+ 0.006= 45.775m

Table6.1

BS(m)	IS(m)	FS(m)	HI(m)	Elevation	Distance (m)	Correction	Corrected Level(m)	Remarks
0.225			49.746	49.521		0.000	49.521	BM(Q)
0.445		1.995	48.196	47.751	46	+0.003	47.754	P1
1.253		2.415	47.034	45.781	32	+0.004	45.785	P2
		1.265		45.769	26	+0.006	45.775	Point A

ΣBS= ΣFS=

1.923 - 5.675 = -3.752

Elevation of (A) – Elevation of(Q) = -3.752

BS(m)	IS(m)	FS(m)	HI(m)	Elevation	Distance (m)	Correction	Corrected Level(m)	Remarks
2.425			48.194	45.769		+0.006	45.775	Point A
2.324		0.533	49.985	47.661	24	+0.007	47.668	P3
		0.473		49.512	32	+0.009	49.5210	BM(Q)

ΣBS= ΣFS=

4.749 - 1.006 = 3.743

Elevation of (Q) – Elevation of (A) = 3.743

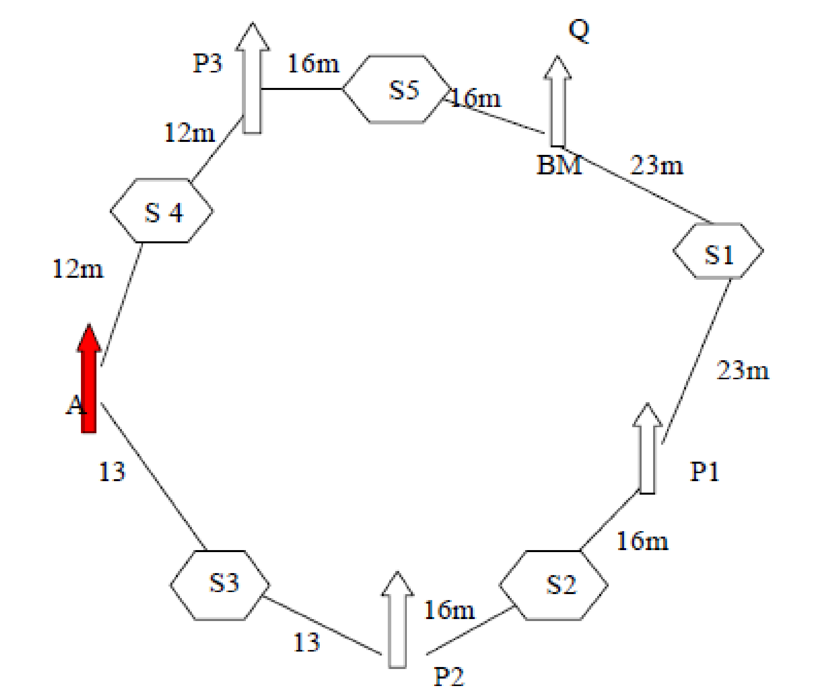


Fig.6.1

VI. Experimental Work:

1- Prepare a leveling table in the field book as shown in table.6.1. Write the elevation of the benchmark in the column headed "Elevation"(assume it to be=49.521 m). Also, write number identification of the benchmark in the column headed "Remarks"
2- The recorder should calculate the height of instrument (HI= Elevation+ B.S
3- Record the total distance between the points in the column headed" Distance"
4- The recorder should then calculate the elevation of the points, Elevation = HI-FS
5- If the error of closure is allowable, adjust the elevations of all of the turning points as well as the elevation of point A by distributing the error of closure on them. The error is distributed according to traveled distance between the traverse points

References:

Experiment 7: CONTOURING FROM GRID (OR SPOT) ELEVATIONS

I. Objective:

Contouring small areas by obtaining the heights of a number of points in the field, plotting these points on the drawing and then interpolating between the plotted points to locate the contours

II. Test Standard

III. Theory:

A contour line may be defined as a line on a drawing representing an imaginary line on the ground having a constant elevation.

Contour lines are drawn in maps to show the configuration or levels of the earth's surface. These maps are very useful for preliminary planning of the projects. They are needed for:

a. Preparation of approximate ground profiles along suggested axes of projects.
b. Checking inter-visibility between distant points.
c. Determining the capacity of a reservoir or a dam.
d. Calculation of earthworks volume.
e. Studying possible routes in highway and railway engineering.
f. Determining watershed lines for hydrological studies….etc.

IV. Apparatus:

- Leveling instument.
- A double right angle prism.
- 20 pins.
- Three range poles.
- A steel tape

V. Procedure:

1- Establish a direction line (line A in figure7.1) parallel to along feature in the area like a building, a fence a road, etc. Record the distance between this feature and the chosen parallel direction line.

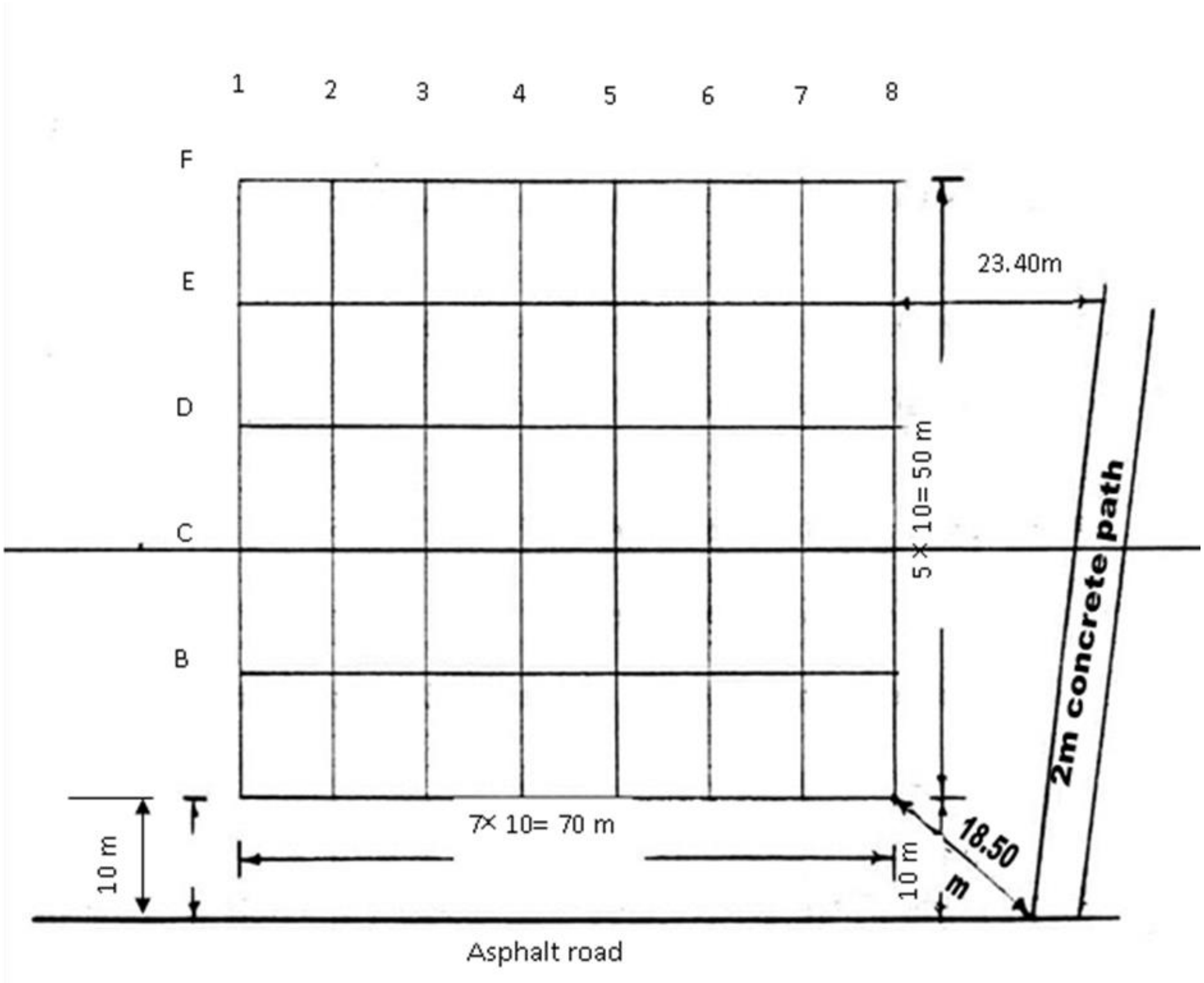


Fig 7.1

2- Set pins every 10m along this line and give them numbers 1,2,3,4, etc.

3- Use the double right angle prism to erect perpendiculars at the already set points 1, 2, 3, … Set points on these perpendiculars also every 10m. Note that it is not necessary to set all grid corners at the same time . Start part by part and remove the used pins after the elevations have been taken. Use the picked up pins to establish new points.

4- Tie the grid to distinguished features in the area so that the contours can be drawn relative to them.

5- Run a leveling with back sights and foresights only (Table 7.1), starting from the given bench mark to a convenient point inside the grid.

6- Take a rod reading at every grid corner and record the reading in the column headed "IS". Calculate the elevation of this corner immediately and record it in the column under "Elevation". Identify the grid corner as the intersection of the lettered and the numbered lines passing through it (A2, C5, D3,,.. etc). Write this identification in the column headed "remarks".

Table 7.1

BS (m)	IS (m)	FS (m)	HI (m)	Elevation	Remarks
2.42			16.70	14.28	Bench Mark
	3.12			13.58	A1
	1.83			14.87	A2
	1.59			15.11	A3
	0.88			15.82	A4
	1.50			15.20	A5
	3.22			13.48	B7
	1.69			15.01	B6
2.28		0.88	18.10	15.82	T.P.
	1.21			16.89	C5

VI. Experimental Work:

1- Use hard and sharp pencils (4H) and good drawing paper.

2- Plot the grid to the scale given by the lab instructor. Write the elevations down at the corresponding grid corner.

3- Consider the contour interval to be 1m if it is not otherwise specified by the lab instructor.

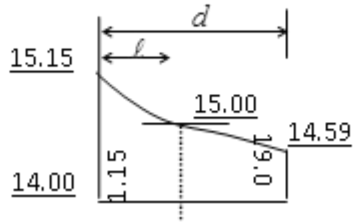
4- Locate the points of intersection of the contour lines with the grid by interpolation. At least two interpolations should be done graphically, two mathematically and the rest can be done by estimation.

5- Connect the points through which each contour line must pass by a freehand curving line.

6- Inter the elevations of these contours in a small gap or break in the lines.

7- It is a normal practice to draw every fifth contour line darker or heavier than the rest.

8- A sample of the contour lines drawing is shown in fig. 7.2



$$\ell = \frac{15.15 - 15.0}{15.15 - 14.59} * d$$

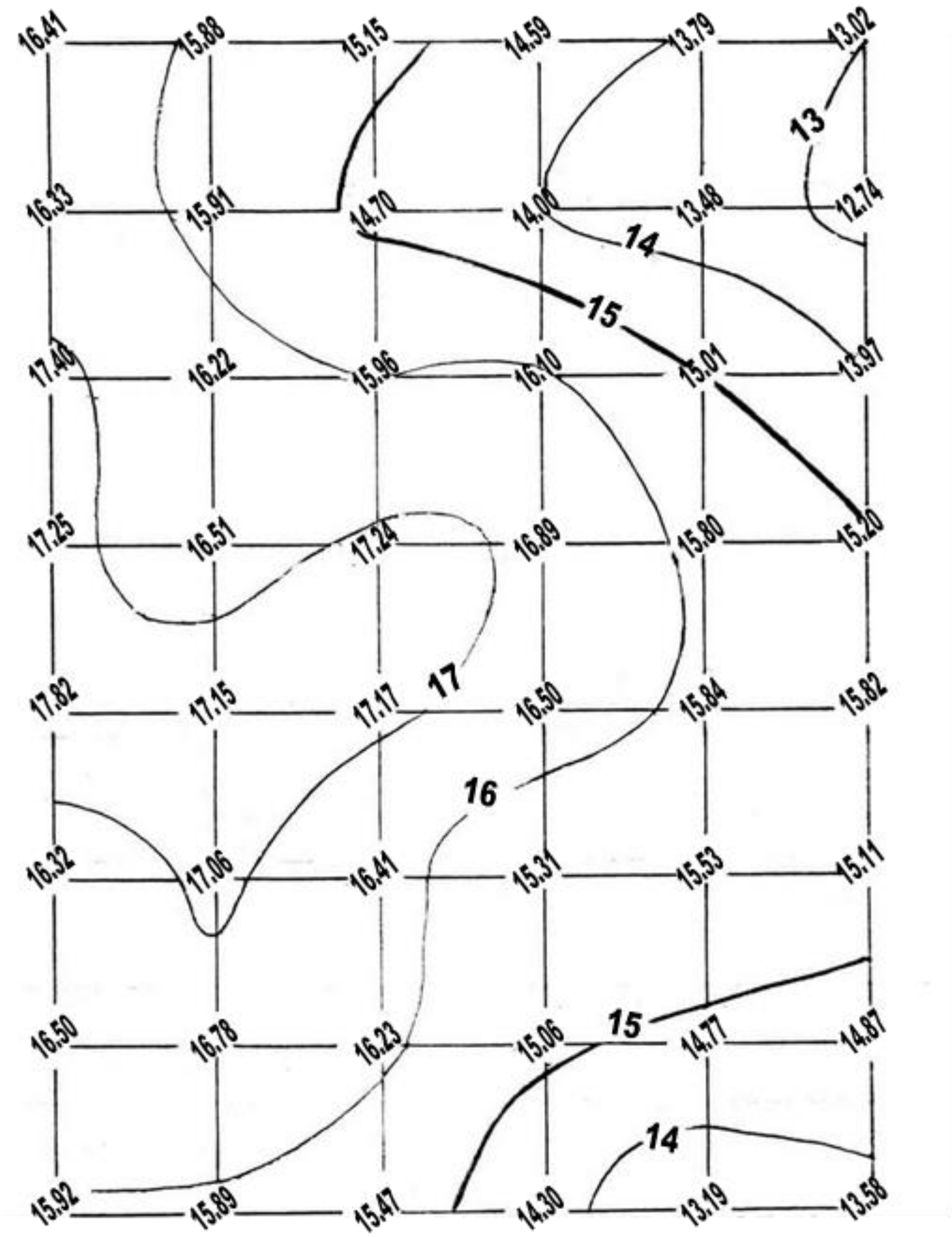


Fig.7.2

References:

Experiment 8: MEASURMENTS OF HORIZONTAL & VERTICAL ANGLES

I. Objective:

The methods of centering, sighting on targets, and taking the readings, or shortly handling the instruments (Theodolite) will be demonstrated and explained in this lab.

II. Test Standard

III. Theory:

- Horizontal angles can be measured between lines forming a closed travers or between lines forming an open traverse
- Vertical angles measured from horizontal by (+) up or(–) down angles

IV. Apparatus:

- Theodolite
- Two targets with tripods (optional) , or 3 pins

V. Procedure:

<u>I Procedure for measuring horizontal angles</u>

1- Set the theodolite on point A, center and level the instrument as mentioned
Since the used theodolite is an electronic one, don't initialize the angle and each student start measurements from a different arbitrary starting angle. Make sure that the readings of the theodolite are reading in an increasing order when the theodolite is rotated from left to right, if not you have to change the polarity of the reading direction.

2- Put the telescope in position **I** (Face Left).
- Sight with vertical hair bisecting the left target(L) or simply sight on the left target, record the reading "a" in the column 3 first raw in table 6.1 (276^o 14' 22")
- Sight on the right target (R) ,record the reading "b" in column 3 second raw (307^o 51' 33")

3- Put the telescope in position **II** (Face Right).
- Sight with vertical hair bisecting the right target, record the reading "c" in the column 4 second raw (127^o 51' 41")
- Sight on the left target, record the reading "d" in column 4 first raw (96^o 14' 34")

4- Record the degree of position **I** , and the mean of the minutes and seconds of the readings (a) and (d) for the left target in the column headed " mean" (276° 14' 28")

5- Write the degrees of position **I** and the mean of the minutes and seconds of the readings (b) and (c) for the right target in the column " mean" (307° 51' 37").

6- Calculate the value of the angle by subtracting the mean reading of the left target from the mean of the right target and record the result in the column headed "Angle".

Angle LAR = 307° 51' 37" -276° 14' 28" =31° 14' 09"

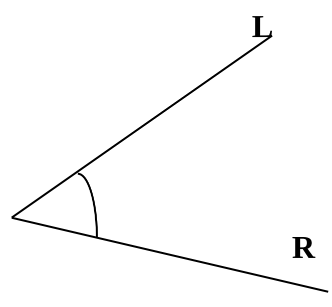
7- Add 360° to the mean reading of the right target if it is smaller than the mean reading of the left target as can be seen in the second example in table 8.1

Angle LAR= 360° + 9° 19' 47" – 337° 42' 34" = 31° 37' 13"

Table 8.1 Example for calculating the horizontal angle by using the means method

Student	PT	I	II	Mean	Angle
A	L	276° 14' 22" (a)	96° 14' 34" (d)	276° 14' 28"	31° 37' 09"
	R	307° 51' 33" (b)	127° 51' 41" (c)	307° 51' 37"	
B	L	337° 42' 40"	157° 42' 28"	337° 42' 34"	31° 37' 13"
	R	9° 19' 52"	189° 19' 42"	9° 19' 47"	

<u>**Mean Angle 31° 37' 11"**</u>



8- The angle LAR can be obtained by calculating both half angles from position I and position II as shown in table 8.2

Table 8.2 Example for calculating the horizontal angle by using the angle difference method

Student	PT	I	II
A	L	276° 14' 22"	96° 14' 34"
	R	307° 51' 33"	127° 51' 41"
	Difference	31° 37' 11"	31° 37' 07"
		Mean	31°37' 09"

9- For any subsequent measurements of the same angle change the initial reading.

10- Calculate the mean of the results of all measurements to find the final value of the angle
(31o 37' 11")

II Procedure for measuring vertical angles

Vertical angles are angles measured in the vertical plane with zero or reference being a horizontal or a vertical line. That is, a vertical angle is not measured from a low point to a high point, but from the horizontal to the high point ,a (+ ve) vertical angle or an angle of elevation, and from the horizontal to the low point ,a(-ve) vertical angle or an angle of depression

Vertical angles are referred to the vertical line in modern instruments and called zenithal angles (or zenithal distances).If the angle lies between 0° and 90° it is an angle of elevation (+ve), otherwise it is an angle of depression (- ve) (between 90° and 180°)

Vertical angles are subject to index error which results from

a- displacement of the vertical circle.

b- lack of adjustment of the vertical circle reading device

The index error is eliminated by sighting in two positions.

1- Sight in position **I**(Face Left) with horizontal hair bisecting the target.
2- Center the bubble of the index level (match both ends in case of split bubble levels) This step is not needed in theodolites with automatic vertical collimation.
3- Take the reading and record it (87^o 22' 43") (table 8.3)
4- Reverse the telescope to position **II** (Face Right) and repeat steps 1,2,and3 . record the reading (272^o 39' 57")
5- Add both readings and compare the results with 360^o. The difference (0^{o}2' 40") is twice the value of the index error.
6- Correct the readings such that their sum agree with 360^o exactly (87^o 21' 23"+ 272^o 38' 37") =360^o.
7- Subtract the corrected angle of position **I** from 90^{o}to get the vertical angle (90^o 00' 00"- 87^o 21' 23"= +2^o 38' 37")

Table 8.3 Calculation of vertical angles

PT	Position I	Position II	Sum	Index Error	Vertical Angle
	87^o 22' 43" 87^o 21' 23"	272^o 39' 57" 272^o 38' 37"	360^o 02' 40" 360^o 00' 00"	-0^o 1' 20"	+ 2^{o}38' 37"

8- Note that the index error is more or less constant per station regardless of the different vertical angles measured.

VI. Experimental Work:

a. Every group will be assigned a point "A" over which they are to set their instruments. Target points "L&R" will be designated by the laboratory instructor.

b. Every student should measure the same horizontal angle LAR but starting from another reading.

c. Every student should measure a different vertical angle.

References:

Experiment 9: MEASURING ANGLES BY REPETITION& HORIZON CLOSURE BY REPETITION

I. Objective:

PART I : Measuring horizontal angles by repetition

To increase the accuracy in measuring horizontal angles, measurement of the angle is repeated four, six times, or eight times. Then the average of these readings will be taken as an indication of the true value of the angle. The principle is to sight on the left and right targets several times without taking intermediate readings. Since there is a possibility of passing the reading 360° once or several times during the measurements, it is necessary to know the approximate size of the angle.
To eliminate the influence of the collimation error and the inclination of the horizontal axis on the angle, half of the measurements should be made with the telescope in position I and half with the telescope in position II.

PART II : HORIZON CLOSURE BY REPETITION

The need sometimes arises to measure the angles between all directions radiating from a point. One of the methods which can be applied in this case is to measure every individual angle by repetition. The sum of all these angles should add up to 360°. Due to the unavoidable accidental errors, however, this condition is rarely satisfied. The closing error, if within allowable range, should be distributed on all measured angles. It will be assumed in this lab that all angles are measured with the same accuracy. Accordingly the closing error can be distributed on the measured angles according to their values

II. Test Standard

III. Theory:

PART I : Measuring horizontal angles by repetition

The value of the angle is determined by dividing the difference between the initial and final readings by the number o f times the angle was turned.

$$\text{Angle} = \frac{\text{Final Reading} - \text{Initial Reading}}{\text{Number of repetitions } n = 6} + \text{multiples of } \frac{360}{n}$$

PART II : HORIZON CLOSURE BY REPETITION

$$\text{Closure error} = \frac{\text{Final reading of last angle} - 360^o}{\text{Number of repetitions}}$$

IV. Apparatus:

- A repetition theodolite.
- Three pins

V. Procedure:

PART I : Measuring horizontal angles by repetition

1. Setup the instrument over point O. It should be understood, that setting up the instrument means centering the instrument exactly over the point and leveling it.

2. In the electronic theodolite, zero the readings by pressing the initialization button, then press the hold button to hold the reading on 0° 00' 00". In the normal repetition theodolites, loosen the upper motion, rotate the alidade until vernier "A" approaches zero (or any definite reading), tighten the upper clamp and with the upper slow motion screw set the"A" vernier exactly on 0^o 00' 00" (or exactly on the initial reading desired).

3 With the telescope in position I sight the left target (L) through the telescope using the lower clamp. Set the vertical hair on the center line of the target exactly using the lower slow motion screw. The reading is still 0^o 00'00" (or the initial reading). Record this reading in Table 9.1 as L_o.

4. Release the hold button, loosen the upper clamp, and sight on the right target (R) through the telescope. With the upper slow motion set vertical hair on the center line of the target.
5. Record the reading L_1 in Table 9.1. This is the single angle value.

6. Hold the reading by pressing the hold button, and loosen the lower notion clamp and sight on the left target. With the slow motion screw bring the vertical hair exactly on the center line of the target the reading is still L_1.

7. Release the hold button, and loosen the upper motion and sight on right target (R.). the reading is now L_2 but it will not be recorded.

8. Repeat steps 6 and 7.
9. The angle has now been turned three times in position I. It is a standard practice to record the third reading before changing positions as shown in Table 9.1. The third reading however, is not used in finding the final value of the angle, but might be helpful in detecting errors.
10. Repeat step 6 and 7 three more times with the telescope in position II.
11. The angle has been turned six times, three times with the position in position I and three times with the telescope in position II. Record the readings of the theodolite in Table 9.1 as L_6.

12. Calculate the value of the angle from the following equation:

$$\text{Angle} = \frac{\text{Final Reading} - \text{Initial Reading}}{\text{Number of repetitions } n = 6} + \text{multiples of } \frac{360}{n}$$

The result should agree with the single value L_1, otherwise the angle is wrong and the measurements should be repeated again.

13. The procedure can be limited to four repetitions or extended to 8 repetitions. If n is the number of repetitions (n is even number), n/2 measurements must be taken in position I and n/2 measurements must be taken in position II. The angle is then calculated from:

$$\text{Angle} = \frac{\text{Final Reading} - \text{Initial Reading}}{\text{Number of repetition } (n)} + m \times \frac{360}{n}$$

Experienced surveyors change the position of the telescope after every measurement (repetition). The measurements are performed as follows

Position	Repetition
I	1
II	2
I	3
II	4
I	odd
II	even

Table 9.1 Measurement of horizontal angle by method of repetition

NO. of REPETITION	n	READING	REMARKS
0	L_0	0^o 00'	Initial reading
1	L_1	125^o 34'	
3	L_3	16^o 43'	
6	L_6	33^o 26'	Final reading
Angle		$\frac{33^o 26'}{6} + 2 \times \frac{360}{6}$	= 125^o 34' 20''

PART II : HORIZON CLOSURE BY REPETITION

1. Set the theodolite over the given point (O). Center and level the instrument carefully.
2. Choose 4 good identifiable paints as targets. Label them A, B, and C in order and in a clockwise direction (See Fig. 9.1)
3. Measure the first angle AOB starting with the initial reading 0^o 00' 00''. Make three repetitions in position I and three repetitions in position II.
4. Use the final reading obtained from the previous angle measurement as an initial reading for angle BOC, repeat the angle three times in position I and three times in position II.
5. Repeat step 4, measuring the angle COD and DOA in a clockwise direction.
6. If the final reading of all angles are used as initial reading for the following angles, and if the same number of repetitions is used in all angles, the horizon closure error will be:

$$\text{Closure error} = \frac{\text{Final reading of last angle} - 360^o}{\text{Number of repetitions}}$$

7. Add the mean angle values and subtract 360^o from their sum to determine the (horizon closure error). Compare the results with that obtained in step 6. This is a check that the average angle values have been calculated correctly.
8. Adjust the mean angle values by distributing the horizon closure equally on the angles so that their sum equals 360^o.

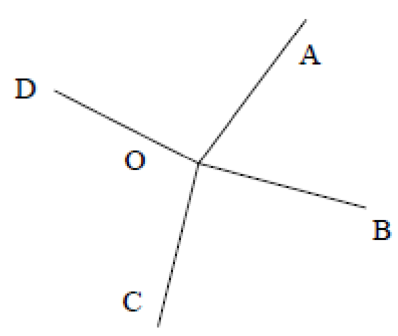


Figure 9.1Selection of the points in the horizon Closure calculation.

A numerical example is shown in table 9.2

Table 9.2 Horizon Closure by Repetition

Angle	R	Value	R	Value
AOB	0	00^o 00'		
	1	65^o 14'		
	6	31^o 25'		
			m	65^o 14' 10''

BOC	0	31^o 25'	0	00^o 00'
	1	129^o 49'	1	98^o 24'
	6	261^o 48'	6	230^o 23'
			m	98^o 23' 50''
COD	0	261^o 48'	0	00^o 00'
	1	349^o 40'	1	87^o 52'
	6	68^o 59'	6	167^o 11'
			m	87^o 51' 50''
DOA	0	68^o 59'	0	00^o 00'
	1	177^o 29'	1	108^o 30'
	6	360^o 01'	6	291^o 02'
			m	108^o 30' 20''

Horizon Closure= $\frac{360^o\ 01' - 360^o\ 00'}{6}$ =10''

	Mean Angle	Correction	Adjusted
AOB	65^o 14' 10''	-2''	65^o 14' 08''
BOC	98^o 23' 50''	-3''	98^o 23' 47''
COD	87^o 51' 50''	-2''	87^o 51' 48''
DOA	108^o 30' 20''	-3''	108^o 30' 17''
	360^o 00' 10''	-10''	360^o 00' 00''

VI. Experimental Work:

1- Measuring the horizontal angle LOR by repetition
2- Measuring four angles between four directions radiating from the given point "0" using the method of repetition

References:

Experiment 10: MEASUREMENT AND CALCULATIONS OF OPEN TRAVERSES

I. Objective:

Traverses are used to find the accurate positions of several points, from which less precise measurements can be made to features to be mapped or located.

II. Test Standard

III. Theory:

Open traverses:
These are mainly used to find the distance and the direction between two points which are neither intervisible nor can be occupied. In an open traverse there are (n+1) points, (n) sides, and (n-1) angles. (Figure 10.1)

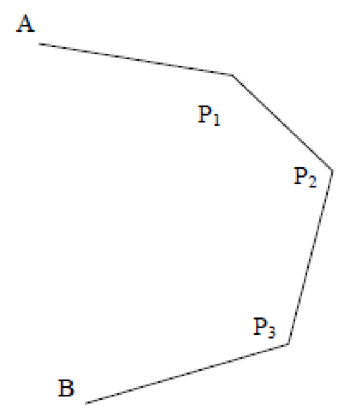


Figure 10.1 Layout of an open traverse

Closed traverses:

Closed traverse are those which either close on themselves (Figure 10.2a) or start and end at fixed points of known coordinates (Figure 10.2b) . In a closed traverse there are (n) points, (n) sides, and (n) angles

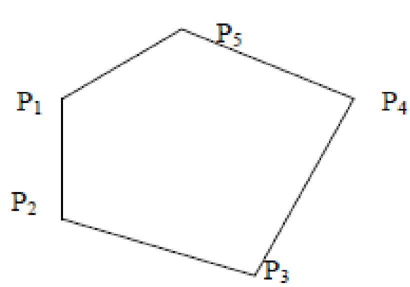


Figure 10.2a Closed Loop traverse

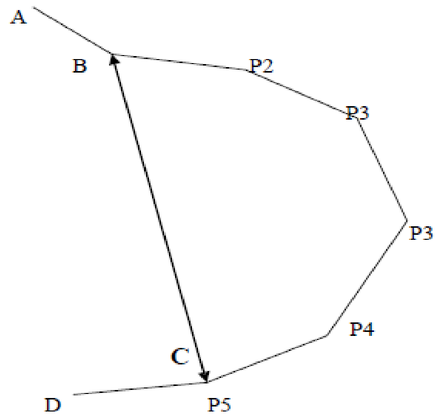


Figure 10.2b Closed traverse between two fixed points

IV. Apparatus:

1. A steel tape.
2. A theodolite.
3. Two plumb bobs
4. Pins

V. Procedure:

1. Walk around the area and locate at least two points B, C as shown in(Figure 10.3) so that points A and C can be seen from B and B and D can be seen from C.

2. In practice all points are marked with wooden stakes or spikes, which are left in ground after finishing the job. However, for the sake of the experimental work, marking the points will be made b pins, which should be picked up after the work has been completed.
3. Measure the distances AB, BC, and CD with the steel tape.
4. Repeat the measurements of the distances in the opposite direction (i.e. DC,CB and BA). If significant differences between both measurements are found, the distances in question should be measured again.
5. Measure the angles ABC and BCD by the method specified by the lab instructor. Remember that one measurement is no measurement and that all angles should be measured at least twice.
6. Measure the azimuth of BC.

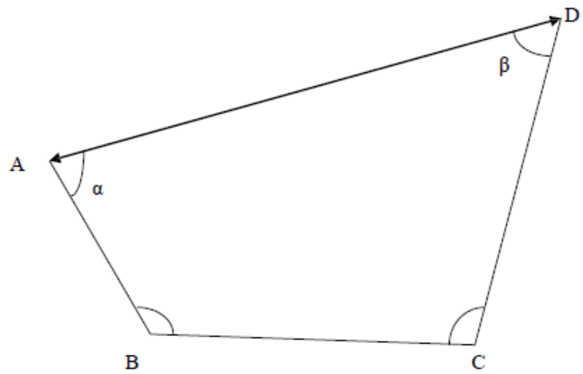


Figure 10

Example:
Assume the azimuth (BC) = 84° 16' 20"

Line	]Forward	Backward	Mean
A-B	163.79m	163.81m	163.80m
B-C	113.74m	113.74m	113.74m
C-D	146.10m	146.14m	146.12m

Angle ABC measurement

#of repetition	Reading
0	00° 00' 00"
1	108° 41' 00"
6	292° 08' 00"

Mean=108° 41' 20"

Angle BCD measurement

#of repetition	Reading
0	00° 00' 00"
1	118° 15' 00"
6	349° 29' 00"

Mean=118° 14' 50"

PT.	Angle	Azimuth	Distance(m)	ΔN(m)	ΔE(m)
A		155° 35' 00"	163.80m	-149.150	+67.710
B	108° 41' 20"				
		84° 16' 20"	113.74m	+11.351	+113.172
C	118° 14' 50"				
		22°31'10"	146.12m	+134.978	+55.964
D					
				Σ= -2.821	Σ= +236.846

$$\text{Tan(AD)} = \frac{+236.846}{-2.821} = -83.958171$$

$(AD) = 180^{\circ} - 89^{\circ}.317600 = 90^{\circ}.682400 = 90^{\circ}\ 41'\ 00''$

(Note that the azimuth (AD) is calculated to the nearest 10")

The distance (AD):

$$AD = \sqrt{(\Delta N)^2 + (\Delta E)^2}$$

$$AD = \sqrt{(2.821)^2 + (236.846)^2}$$

=236.863 m

$$AD = \frac{\Delta N}{\text{Cos(AD)}} = \frac{-2.821}{\cos(90.68240)} = 236.863 \text{ m}$$

$$AD = \frac{\Delta E}{\text{Sin(AD)}} = \frac{+236.846}{\text{Sin}(90.6824)} = 236.863 \text{ m}$$

The end angles:

(AB)	155° 35' 00"	(DA)	180°+90°41'00"
-(AD)	90° 41' 00"	-(DC)	180°+22°31'10"
α	64° 54' 00"	B	68° 09'50"

A	64° 54' 00"
B	108°41'20"
C	118° 14' 50"
D	68° 09'50"
Σ	360° 00' 00"

VI. Experimental Work:

Making the necessary measurements to be able to compute:

1. The distance AD.
2. The end angles α & β included between the line AD and both first and last traverse sides AB and CD.

References:

Experiment 11: MEASUREMENT AND CALCULATIONS OF CLOSED TRAVERSES

I. Objective:

Measurements and calculation of closed traverse, which include azimuth, departure, latitudes, coordinates and areas

II. Test Standard

III. Theory:

Closed traverses:

Closed traverse are those which either close on themselves (Figure 11.1a) or start and end at fixed points of known coordinates (Figure 11.1b) . In a closed traverse, there are (n) points, (n) sides, and (n) angles

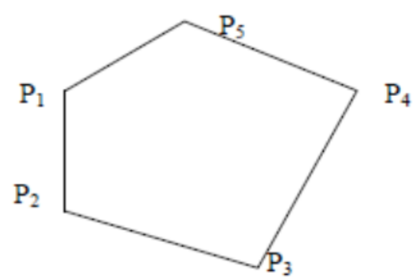


Fig 11.1a Closed Loop traverse

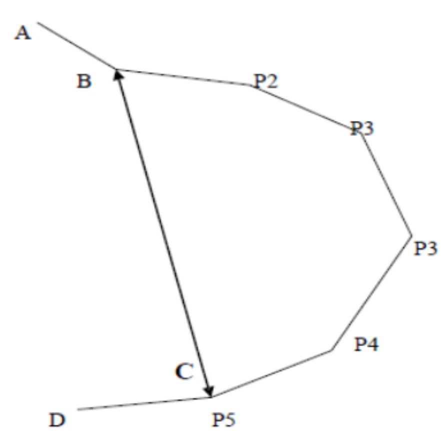


Figure 11.1b Closed traverse between two fixed points

IV. Apparatus:

- Theodolite.
- Steel tape.
- Four range poles.
- Plumb bobs.
- Four Chaining pins.

V. Procedure:

1. If the traverse points are not given, walk around the area and choose 4 (or 5) points so that the distance between, any two successive- points is more than 40m and can be taped easily. Label these points A, B, C, and D and fix pins at their locations.
2. Measure the angles by six times repetition as mentioned. Note that all angles are measured clockwise from a back point to a fore point.
3. Compare the sum of all angles measured with the geometric sum $(n \pm 2) \times 180°$. (Use +ve for external angles and -ve for internal angles). The difference is the angular closing error
4. If the angular closing error exceeds 30" X n, where n is the number of the angles or the number of the closed traverse points, the angles should be measured again.

   Generally, lab time is not sufficient for repeating incorrect measurements. It is recommended, therefore, to concentrate on the measurements and to do them at most care.
5. Measure the distances between the points twice using, the steel tape. The difference between the two values should not exceed 1cm, otherwise a third measurement must be taken.

Traverse computations and numerical example:

Point	Angle	Distance (m)
A	74° 50' 40"	86.85
B	79° 26' 30"	
C	103° 00' 10"	69.60
D	102° 42' 00"	55.02
A		73.33

Steps of the calculation :

1. Check the angular closing error $\Delta\beta$ (= - 40") which supposed to be calculated in the field(Figure 11.2).
2. Correct the measured angles by distributing the angular closing error $\Delta\beta$ equally on them ($-\frac{40''}{4} = -10''$). It is obvious that the arithmetic sign of the correction is opposite to that Of the error. In this example the correction is +10" per angle.
3. Assume the azimuth of the first line AB if not given ($\alpha = 130^o\ 33'\ 20''$).
   Calculate the azimuth of all other lines using the corrected angles. The formula is
   Next azimuth = previous azimuth + corrected angle +180°
   Continue your calculations until the first azimuth (AB) is reached again. You should get the same value you started with.
4. Compute N- and E- components for all lines

$$\Delta N_i = D_i \times \cos\alpha_i$$

$$\Delta E_i = D_i \times \sin\alpha_i$$

5. Calculate the components of the linear closing error Δr by adding all North components [ΔN] And all East components [ΔE].

$\Delta r_N = [\Delta N] = [D.\cos\alpha] = (+0.018m)$

$\Delta r_E = [\Delta E] = [D.\sin\alpha] = (-0.033)$

6. Compute the linear closing error:

$$\Delta r = \sqrt{(\Delta r_N)^2 + (\Delta r_N)^2} = 0.038m$$

7. Compute the relative error

$$\Delta r_r = (\Delta r / [R]) = \frac{1}{([R]/\Delta r)} = \frac{1}{(284.80/0.038)} = \frac{1}{7500}$$

In normal practice, the relative error should not exceed a definite ratio, e.g., 1/5000for desert areas, 1/10000for farm lands and 1/20000for city surveys.

8 .Distribute the linear closing error on the components of the lines applying the compass rule

Correction to North Components	Correction to East Components
$V_{Ni} = \frac{-[\Delta N]}{[D]} * Di$	$V_{Ei} = \frac{-[\Delta E]}{[D]} * Di$

For the second line BC as an example:

$V_{N2} = (-0.018/284.8) * 69.6$

$= -0.004m$

$V_{E2} = (0.033/284.8) * 69.6$

$= +0.008m$

9. Calculate the latitudes and departures by adding the corrections to the components algebraically

10. Give coordinates to the points by assuming a reasonable coordinate system, i.e. assume coordinates for point A. ($N_A = +100.00$ m, $E_A = +100.00$m)

11. Compute the area of the traverse from the coordinates as shown in table 9.3 .Despite the different assumptions taken by the different students in the same group, the area of the traverse must be the same.

12. Carry all your computations to the nearest (mm), Round off final values to the nearest (cm) And the area to the nearest $0.5m^2$.

Angle Measurements by Repetition

#of repetition	Angle ABC	Angle BCD	Angle CDA	Angle DAB
1	19° 26' 00"	103° 00' 00"	102° 42' 00"	74° 51' 00"
3	238° 19' 00"	309° 00' 00"	308° 06' 00"	224° 34' 00"
6	116° 39' 00"	258° 01' 00"	256° 12' 00"	89° 04' 00"
mean	19° 26' 30"+ 60°00' 00"	43° 00' 10"+ 60°00' 00"	42° 42' 00"+ 60°00' 00"	14° 50' 40"+ 60°00' 00"
Mean	79° 26' 30"	103° 00' 10"	102° 42' 00"	74° 50' 40"

Angle	
A	74° 50' 40"
B	79° 26' 30"
C	103° 00' 10"
D	102° 42' 00"
∑ -	359° 59' 20" 360° 00' 00"

Closing error = - 40"(acceptable)

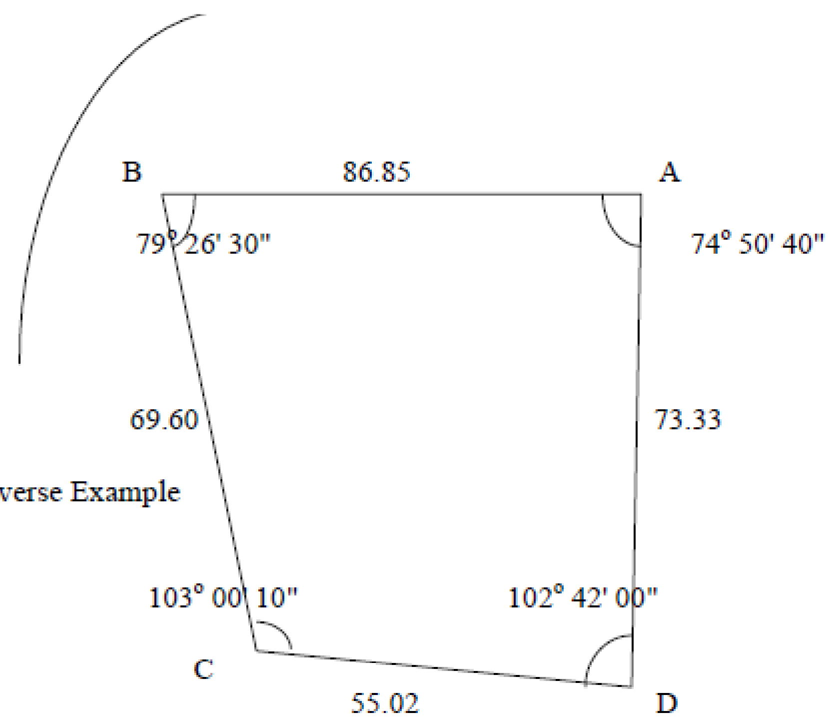


Fig. 9.1 Closed Traverse Example

Pt	Angle	Azimuth α	Distance (M)	$\Delta N_i = D_i \cdot \cos\alpha_i$ (m)	$\Delta E_i = D_i \cdot \sin\alpha_i$(m)
A	+10" 74° 50' 40"	130°33'20"	86.85	-5 -56.469	+10 +65.987
B	+10" 79° 26' 30"	30°00'00"	69.60	-4 +60.275	+8 +34.800
C	+10" 103° 00' 10"	313°00'20"	55.02	-4 +37.527	+6 -40.235
D	+10" 102° 42' 00"	235° 42' 30"	73.33	-5 -41.315	+8 -60.584
A					
∑ -	359° 59' 20" 360° 00' 00"		284.80	+0.018	-0.033
Δβ	= - 40"				

pt	Latitude(m)	Departure (m)	Northing(m)	Easting(m)
A	-56.474	+65.997	+100.00	+100.00
B	+60.271	+34.808	+43.526	+165.997
C	+37.523	-40.229	+103.797	+200.805
D	-41.320	-60.576	+141.320	+160.575
A			+100.00	+100.00
	0.000	0.000		

pt	N(m)	E(m)	(A) N_i+N_{i+1} (m)	(B) E_i-E_{i+1} (m)	(A).(B) m^2	(C) N_i-N_{i+1} (m)	(D) E_i+E_{i+1} (m)	(C).(D) m^2
A	+100.00	+100.00						
			143.52	-66.00	-9472.32	+56.48	+266.00	+15023.68
B	+43.52	+166.00						
			+147.32	-34.80	-5126.74	-60.28	+366.80	-22110.70
C	+103.80	+200.80						
			+245.12	+40.22	+9858.73	-37.52	+361.38	-13558.98
D	+141.32	+160.58						
			+241.32	+60.58	+14619.17	+41.32	+260.58	
A	+100.00	+100.00						+10767.17

Double Area = 9878.84 + 9878.84-

Area of the traverse ABCD= $\frac{9878.84}{2}$ =4939.5 m^2

VI. Experimental Work:

a. Measuring all angles and distances of the traverse.
b. Adjusting the traverse.
c. Calculating the area of the traverse

References:

Experiment 12: Training on Planimeter

I. Objective:

Training students on planimeter for area measurement on maps and drawings

II. Test Standard

III. Theory:

A very precise instrument for quick and accurate determination of areas on blueprints, maps, photographs, and drawings. Simply follow the outline of the area with the tracer. The revolution of the measuring wheel to either direction is sensed by the electro shaft-encoder which generates pulses to be processed by the built-in processor.

IV. Apparatus:

Planix Digital Planimeter

Fig.11.1

Measuring range: 11.8″ width x unlimited length, 11.8″ diameter circle.

Resolution: one digit corresponds to 0.1 cm^2 or 0.01 in^2.

Accuracy: better than ±0.2%.

Power: rechargeable Ni-Cad battery (included) provides 30 operating hours; AC adapter/recharger. Battery power saving automatically turns the unit off after more than three minutes of dormancy.

Dimensions: 5.9″ x 9.4″ x 1.5″.

V. Procedure:

• Cordless operation – powered by rechargeable Ni-Cad battery!

• Direct digital readout of traced area in unit you select – cm^2, m^2, km^2, in^2, ft^2, or acres. No table references, no calculations.

• Accumulative measurement of different areas.

• Push button averaging of several measurements of the same area.

• "Hold" function freezes readout to prevent accidental loss of result.

• Measures drawings when vertical scale differs from horizontal scale.

• Zero setting by push button.

Automatic area computation by selected scale factors. Scale factor is stored when switch is turned off. Metric or English scale convertible can be displayed in terms of cm^2, m^2, km^2, in^2, ft^2, or acre. When a certain area cannot be covered by cm^2 display due to overflow, the display unit shifts automatically to m^2, and then to km^2. Likewise, the shift is made from in^2 to ft^2, and then to acre. The same area measured several times may be averaged by a single push button. The measured figure on the display is frozen by a "hold" button to prevent an inadvertent loss of the result. When the previous measurement frozen on the display by the "hold" button is released, accumulative measurements are made on top of it.

VI. Experimental Work:

- Average area measurements
- Area measurement with different scales
- Accumulative area measurments
- Metric & English area units

References:

Experiment 13: Total Station Applications

I. Objective:

Training students on total station.

II. Test Standard

III. Theory:

Total station can measure, record horizontal, and vertical angles together with slope distances

Microprocessor performs the following operations:

- averaging multiple angle measurements.
- averaging multiple distance measurements.
- determing horizontal and vertical distances
- determing X(easting),Y(northing) and Z coordinates.
- determing remote object elevation and distance between remote points.

IV. Apparatus:

Total station

Prism

V. Procedure:

All total stations programs require that the instrument station (occupied point) and at least one reference station (backsight point) be identified so that all subsequent tied – in- stations can be defined by their (X) easting, (Y) northing and (Z) elevation coordinates .

So the instrument station coordinates and elevation together with azimuth to reference station (or coordinates) can be entered in the field or uploaded prior to going out to the field . After setup and before the instrument has oriented for surveying, the height of instrument above the instrument station and prism height must be measured and recorded

VI. Experimental Work:

1-Point Location:

After the instrument has been properly oriented the coordinates (Northing, Easting and Elevation) of any sighted point can be determined ,displayed and recorded in the following format (N,E,Z)

2- Missing Line Measurements:

This program enables the surveyor to determine the horizontal and slope distance between any two sighted points and well as the direction of the lines joining those sighted points

3- Resection:

This technique permits the surveyor to set up the total station at any convenient position and then to determine the coordinates and elevation of that instrument position by sighting previously coordinated reference stations.

4- Azimuth:

When the coordinates of the instrument station and BS reference station have been entered in to Instrument processor, the azimuth of a line joining any sighted points can be displayed and recorded

5- Area Computation:

While this program has been selected, the processor computes the area enclosed by a series of measured points

6- Layout or Setting- Out Points :

After the station number, coordinates, and elevations of the layout have been uploaded into the total station, the layout software enables the surveyor to locate any layout point by simply entering that point's number prompted by the layout software.

7- Remote Object Elevation:

The surveyor can determine the heights of inaccessible points by simply sighting the pole- mounted prism while it is held directly under the object. When the object itself is then sighted the object height can be promptly display

References:

Experiment 14: GPS Applications

I. Objective:

Training students on GPS

II. Test Standard

III. Theory:

GPS receivers use triangulation to calculate the user's exact location
Precise microwave signals are transmitted from the satellites, allowing a GPS receiver to determine its location, speed and direction
Three spheres intersect at a point; there are 3 distances or ranges to resolve, latitude, longitude and height.
Tracking four satellites is required in order to correct the receiver's clock error. Here there are four ranges to resolve, latitude, longitude, height and time.

GPS TECHNIQES
-Static Positioning
- RTK(Real Time Kinematic

IV. Apparatus:

GPS receivers (Base & over)

V. Procedure:

GPS measurements are referenced to the 1984 World Geodetic System reference ellipsoid, known as WGS84.
It is better to display and store results in terms of a local coordinate system. Before you start a survey:
Choose a coordinate system. Depending on the requirements of the survey, you can choose to give the results in the national coordinate system, a local coordinate grid system, or as local geodetic coordinates.
When you have chosen a coordinate system, search your survey archives for any horizontal and vertical control points in that coordinate system that are in the area to be surveyed. You can use these to calibrate a GPS survey

VI. Experimental Work:

Local Coordinate Systems
A local coordinate system simply transforms measurements from a curved surface (the earth) onto a flat surface (a map or plan). Four important elements constitute a local coordinate system:
Local datum
Datum transformation
Map projection
Calibration (horizontal and vertical adjustments)
When you survey using GPS, consider each of these

References:
