Ministry of high Education and Scientific Research

Southern Technical University

Technological Institute of Basra

Department of Surveying Techniques

Learning package

Engineering Surveying (S213)

For

Second year students

By

Dr. Aqeel Mohammed

Lecturer

Dep. Of Surveying Techniques

2025

Course Description

Course Name:
Engineering Surveying
Course Code:
S213
Semester / Year:
Semester
Description Preparation Date:
14/ 05/ 2025
Available Attendance Forms:
Attendance only
Number of Credit Hours (Total) / Number of Units (Total)
60 hours/4 hour weekly/4 unit
Course administrator's name (mention all, if more than one name)
Name: Dr. Aqeel Mohammed Email: aqeel.almosawi@stu.edu.iq
Course Objectives
1. Train students to use surveying tools and instruments such as tape measures, levels, theodolites, total stations, and GPS systems accurately in both field and office work. 2. Develop students' skills in calculating and measuring land areas using various traditional and digital surveying methods. 3. Enable students to compute earthwork volumes for excavation and embankment using appropriate surveying techniques. 4. Train students in performing calculations for horizontal and vertical curves and accurately setting them out in the field for road and infrastructure projects. 5. Equip students with the ability to set out engineering structures on the ground, such as buildings, bridges, and road centerlines, with high precision. 6. Teach students how to perform surveying calculations to determine missing lengths, directions, and angles, particularly for redefining land parcel boundaries. 7. Strengthen students' ability to read, interpret, analyze surveying and topographic maps, and convert between field data and graphical representations. 8. Prepare students to use modern surveying software such as AutoCAD Civil 3D and GIS, and apply digital data processing techniques in surveying. 9. Prepare students for fieldwork with teamwork skills and adherence to occupational safety standards, including proper organization and technical reporting.

10. Provide students with a solid understanding of applied surveying principles and their integration into infrastructure projects such as water networks, roads, and buildings.

Teaching and Learning Strategies

1. **Cooperative Concept Planning Strategy.**
2. **Brainstorming Teaching Strategy.**
3. **Note-taking Sequence Strategy.**

Course Structure

Weeks	**Hours**	**Required Learning Outcomes**	**Unit or subject name**	**Learning method**	**Evaluation method**
1	4hours	1. Understanding the basics of surveying and engineering measurements 2. Learning different area calculation methods Apply various methods to calculate areas Distinguishing between types of section plotting 3. Compute volumes using engineering laws Identify mapping symbols and terms 4. Analyze vertical profiles	1. Introduction to engineering surveying, types of shapes, area symbols, and map symbols 2. Straight-line segments methods (Trapezoidal & Simpson's Rule) 3. Use of coordinates and offsets in area computation 4. Longitudinal and cross-section measurements 5. Volume calculation using Average End Area Method 6. Types of surveying: leveling, aerial, and road surveying; map codes and special symbols 7. Vertical profiles and their data representation 8. Types of vertical curves (Simple, Compound, Parabolic) 9. Types and characteristics of horizontal curves 10. Curve design methods and tangent computation 11. Electronic layout using Total Station 12. Application of horizontal curves on real maps	1. Theoretical explanation using diagrams and case studies 2. Using mathematical and graphical models 3. Practical applications using surveying maps 4. Field measurements and graphical plotting 5. Exercises using formulas and sample data 6. Applications using topographic maps 7. Hands-on exercises with road and terrain profiles	Weekly, Monthly, Daily, and Written Exams, and Final Term Exam.
2	4hours				
3	4hours				
4	4hours				
5	4hours				
6	4hours				
7	4hours				
8	4hours				
9	4hours				
10	4hours				
11	4hours				
12	4hours				
13	4hours				
14	4hours				
15	4hours				

		Compare types of vertical curves 5. Understand horizontal curves and their properties Calculate curve elements accurately 6. Apply electronic curve setting methods Apply curves to topographic maps 7. Define and use coordinate systems Use GPS/GIS in site layout 8. Apply calculations in real case projects	13. Coordinate systems (local and global) 14. Coordinate applications in real-world surveying 15. Integration of area, volume, and coordinate data for engineering projects	8. Speed and elevation relation computations 9. Curve plotting using various elements 10. Solving problems using surveying laws and tools 11. Field practice with electronic instruments 12. Map-based exercises 13. Point plotting using surveying coordinates 14. Training on GPS/GIS software 15. Final review with real case simulations	

Course Evaluation

"The distribution of grades is as follows: 20 points are allocated to the midterm theoretical examinations of the first semester, 20 points to the midterm practical examinations for the same semester, 10 points to daily assessments and continuous evaluation, and 50 points to the final examination."

Learning and Teaching Resources	
Required textbooks (curricular books, if any) Main references (sources)	المسح الهندسي والكادستر ائي/ تأليف زياد عبد الجبار البكر/ دار الكتب والنشر/ جامعة الموصل 1993
Recommended books and references (scientific journals, reports...)	• المساحة (الجزء الأول) تأليف بي. سي ز بينميا/ ترجمة زياد عبد الجبار البكر 1988 • المساحة (الجزء الأول) تأليف بي. سي ز بينميا/ ترجمة زياد عبد الجبار البكر 1988 • المسح الهندسي (الجزئين الأول والثاني)/ تأليف دبليو ب سكوفليد/ ترجمة رياض شعان 1983 • Surveying Vol. 1 & Vol. 2) / B.C. Punmi a/Standard Book House, Delhi, India. 1978. • Engineering Surveying (Vol. I & Vol.2)/ W. Scho field / Newness – Butter Woths/ London / Britain. 1978. • Surveying for Engineers / J. Uren. & W.F. Price / MacMillan / London/ Britain . 1985. • Manual of GPS, Total station, Autocad disk land, Auto disk Civil 3D

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Overview

A –Target population :-

Second-Year Students
Technological Technical Institute in Basra
Department of Surveying Technologies

B –Rationale :-

Introduce students to the importance of engineering and cadastral surveying as a foundation for engineering works and land planning. Highlight its role in accurately determining locations, boundaries, and areas.

C –Central Idea :-

1. Introduction to the basics of engineering and cadastral surveying and their applications.
2. Highlighting the importance of surveying in engineering projects and land planning.
3. Preparing students for area calculation methods as a foundation for future field measurements.

D – Performance Objectives

1. Students will define and distinguish between engineering and cadastral surveying.
2. Students will explain the importance of surveying in engineering and land/property projects.
3. Students will identify the basic methods used to calculate areas.

Introducing engineering survey, work areas, engineering units

- Engineering survey is that branch of surveying that seeks to provide the best ways to solve the problems facing the surveyor in engineering projects that are implemented in the manner of (ground survey).
- The interest of this type of surveys appears "clearly" in the calculations (the areas and volumes of the vast lands, determining the paths of roads, including horizontal and vertical curves, as well as many construction surveys that are usually attributed to the surveyor).

Work Fields

1- Areas

This part deals with calculating regular and irregular areas, whether they are on the ground or on the map. It is also concerned with the different methods of calculating areas (mathematically) or using devices and tools such as (the planometer), and software may be used in this field.

2- Volumes

The same applies to volumes, some of which are regular and irregular, and we mainly emphasize the volumes resulting from the earthworks of road surveys and their longitudinal sections and cross-sections, in addition to the volumes resulting from contour maps, which are represented in cutting heights and filling in depressions.

3- Road survey:

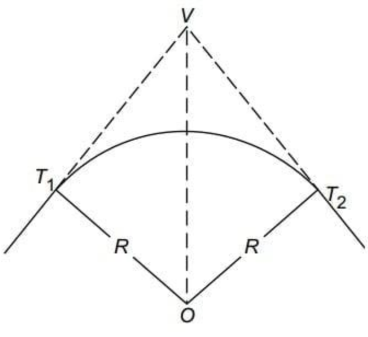
Road survey works are numerous and extensive, and may overlap with road and bridge engineering works. In all, they are of two types; The first: the technical works related to the road such as (traffic volume, number of lanes, acceleration and deceleration lanes, shoulders and lateral inclination to overcome the central force when bending, construction costs ... and others) and the second type is specific to road planning and engineering trajectory identification; Such as (determining the coordinates of the track, vertical curves, horizontal curves...), where the surveyor's work is concentrated in the second type based on the data of the first type (artworks).

4- Vertical curves:

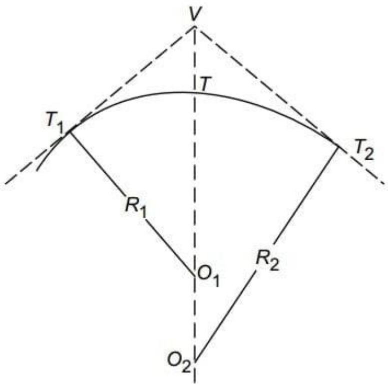
They are of two types (convex and concave) and are represented in bridges and tunnels, as well as their use in plains and slopes on the one hand, and hills and heights on the other. It will be discussed in detail later.

5- Horizontal curves:

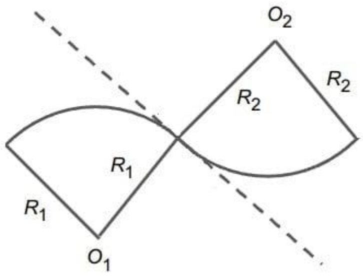
They are of three types: (simple, compound, and transitional), as shown in the figure.



Simple Circular Curve



Compound Curve



Reverse Curve

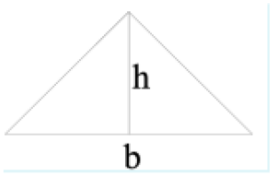
Structural survey: It deals with the following

- Locating and aligning the buildings.
- Verticality of columns (electricity, buildings...)
- Barrages, water and sewage pipes.
- Locating and aligning bridges.
- Locating and aligning the electrical and telephone lines and determine their integrity.
- In addition, other construction works.

Uniform figures areas

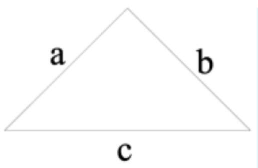
- Triangle area

$$A = \frac{1}{2} * b * h$$



- If you know the three sides:

$$A = \sqrt{S(S-a)(S-b)(S-c)}$$



S is circumference of a tringle

$$S = \frac{a+b+c}{2}$$

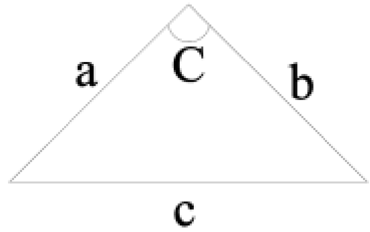
Or

$$A = \frac{b}{2}\sqrt{[a^2 - \left(\frac{a^2+b^2-c^2}{2*b}\right)^2]}$$

a, b , c are sides of triangles

- If two adjacent sides and an included angle are known,

$A = \frac{1}{2} * a * b * \sin(C)$



a, b = sides of triangles

< C = angle between two sides

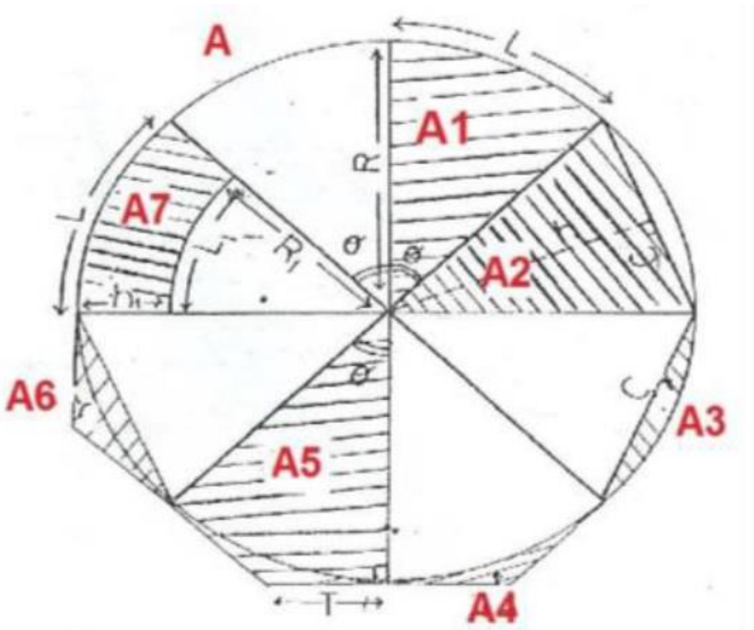
- If you know a side and two angles

$$A = \frac{b^2}{2}\left[\frac{\tan(A) * \tan(C)}{\tan(A) + \tan(C)}\right]$$

sin rule: $\frac{a}{\sin(A)} = \frac{b}{\sin(B)} = \frac{c}{\sin(C)}$

cos rule: $c^2 = a^2 + b^2 - 2 * a * b * \cos(C)$

- Circle Areas $A = \pi * R^2$



- Area of a circle sector $A_1 = \pi * R^2 * \frac{\theta}{360}$

Circumference of a circle $L = 2\pi * R$

Circle sector length $L = 2\pi * R * \frac{\theta}{360}$

- The area of the triangle part (A_2) $A_2 = \frac{1}{2} * h * C \quad or \ = \frac{1}{2} * R^2 * \sin(\theta)$
- The area of a circular segment or segment (A_3), which is (the part between the hypotenuse and the arc)

$$A_3 = \frac{1}{2} * R * L - \frac{1}{2} * h * C = \frac{1}{2} * (\frac{\pi}{180} * \theta - \sin(\theta))$$

- The area of the outer segment (A_4), which is (the part between the arc and the tangents)

$$A_4 = R * T - \frac{1}{2} * R * L = \ R^2(\tan\left(\frac{\theta}{2}\right) - \frac{\pi}{720} * \theta)$$

- Area of sector and outer segment (A_5)

$$A_5 = R^2 * \tan(\frac{\theta}{2})$$

- Area of secant and exterior segment (A_6) where (T) is the length of the tangent

$$A_6 = \tan\left(\frac{\theta}{2}\right) * (R * \sin(\frac{\theta}{2}))^2$$

- The area of the circular ring (A_r) $A_r = \pi({R_1}^2 - {R_2}^2)$

Overview

A –Target population :-

Second-Year Students
Technological Technical Institute in Basra
Department of Surveying Technologies

B –Rationale :-

Teaching area calculation with columns helps students accurately measure land with equal or unequal intervals for practical surveying applications.

C –Central Idea :-

1. Understanding area calculation by placing columns at equal intervals.
2. Learning to calculate area when column intervals are unequal.
3. Applying these methods in practical land surveying tasks.

D – Performance Objectives

1. Students will apply methods to calculate area-using columns placed at equal intervals.
2. Students will calculate area with columns placed at unequal intervals.
3. Students will demonstrate accuracy in practical land measurement exercises using these techniques.

Method of measurements and computation of areas

- Field Measurements
- Map Measurements

1. Field Measurement

- Dividing the piece into triangles this method is used when the ground is flat and free of beams, where the piece is divided into triangles so that the lengths of its sides can be measured or some of the lengths and angles confined using the tape only. As in figure (1-1a)
- Or use the flat board with the tape (where the angles confined by the protractor are measured from the diagram drawn on the plate in Figure (1-1b)

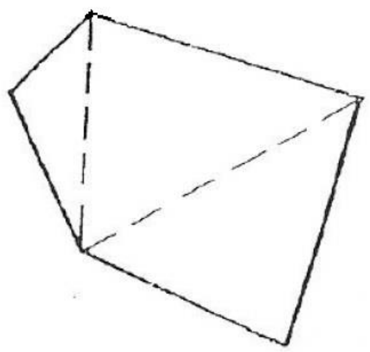


Figure 1-1 a

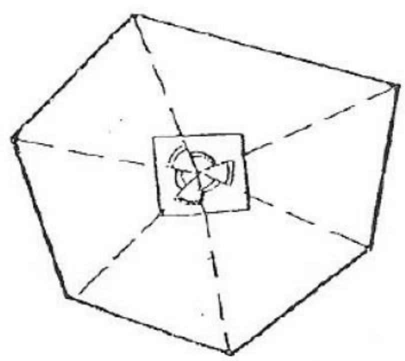


Figure 1-1 b

If the segment's borders are irregular, the adjacent parts can be divided into small triangles. As in Figure (1-1 c). or by following the method of addition and deletion as in Figure (1-1d) or erecting columns from the ribbing line or scanning near the zigzag borders to those borders as shown in the immediate method (where all lengths are measured using the tape).

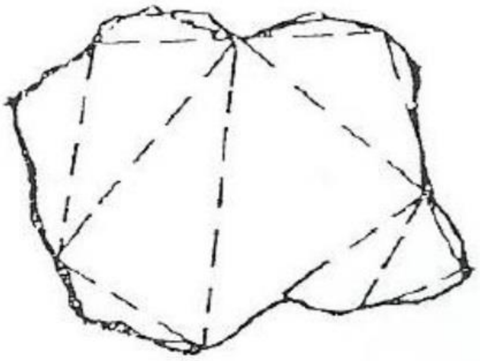


Figure 1-1 c

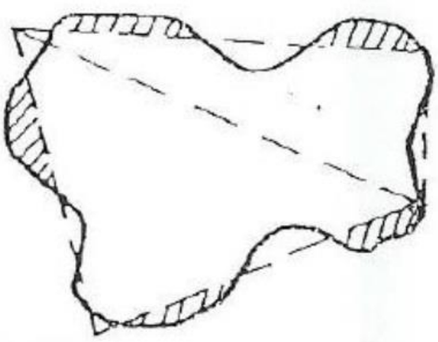
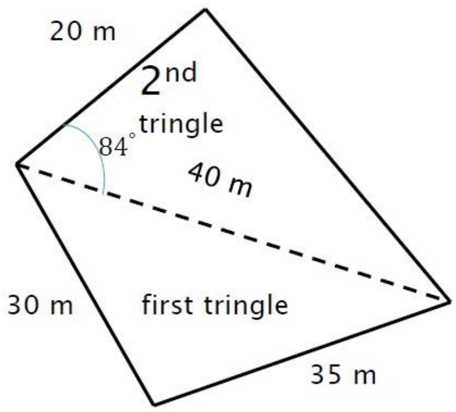


Figure 1-1 d

Example/ The area of a castle land was evaluated by dividing it into two triangles، where the lengths of the three sides of the first triangle and the lengths of two illustrated ministerial sides of the second triangle were measured, as shown in the figure below. It is required to calculate the s.



Solution/

For the first tringle

$$S = \frac{a+b+c}{2}$$

$$S = \frac{30+35+40}{2} = 52.5\ m$$

$$A = \sqrt{S(S-a)(S-b)(S-c)}$$

$$A_1 = \sqrt{52.5 * (52.5-30) * (52.5-35) * (52.5-40)}$$

$$A_1 = 508.33\ m^2$$

For the 2nd tringle

$$A = 0.5 * a * b * \sin(C)$$

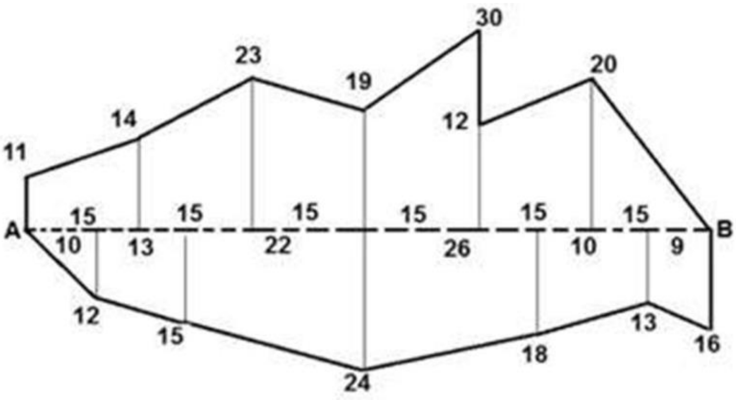
$$A = 0.5 * 20 * 40 * \sin(84) = 397.81\ m^2$$

$$A_{total} = 508.33 + 397.81 = 906.14\ m^2$$

- The area of land parcels or regions is often needed as part of a volume calculation, for instance, to determine the amount of fertilizer to be applied to a paddock or to determine runoff for stream flow analysis. The legal title description of a land allotment also shows the area.
- Regular straight lines or circular arc boundaries do not always contain land parcels, especially when they front watercourses or ridgelines. Methods for surveying these boundaries and computing the enclosed areas are as follows:

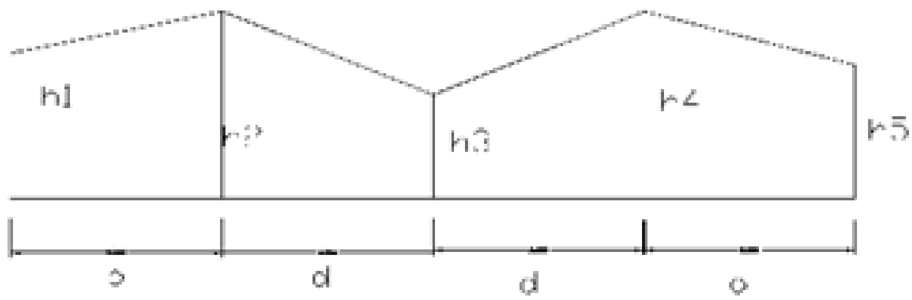
A. Average Offset Formul

$$A = \frac{h_1+h_2+h_3+\cdots+h_n}{n} * L$$



B. Trapezoidal Rule

This law is used when the segment boundaries are straight or broken، or when the equal interval between the columns is short so that the curved boundaries approach to the straight lines between the columns.



$$A_{total} = \left(\frac{h_1 + h_n}{2} + h_2 + h_3 + \ldots\ldots + h_{n-1}\right) * d$$

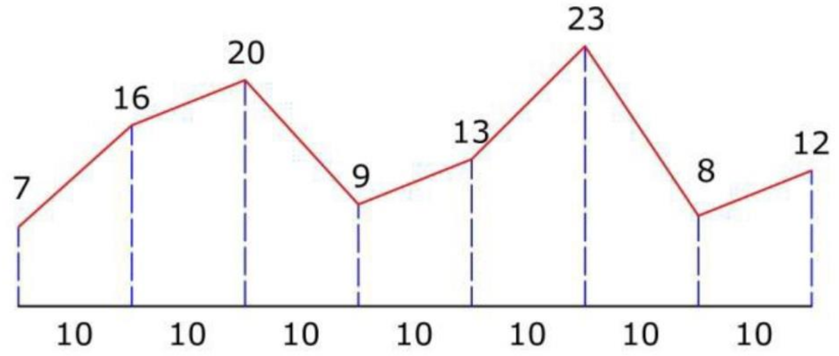
C. Simpson's Rule

This law is used in the form of arcs or curves, which give more accurate results than the trapezoid law.

$$A = \frac{d}{3}[h_1 + h_n + 4(h_2 + h_4 + \ldots\ldots h_{n-1}) + 2(h_3 + h_5 + \ldots. + h_{n-2})]$$

$$n = odd\ number$$

Example: Find the area of the Fig. below by using (Average& Trapezoidal) methods



Sol.

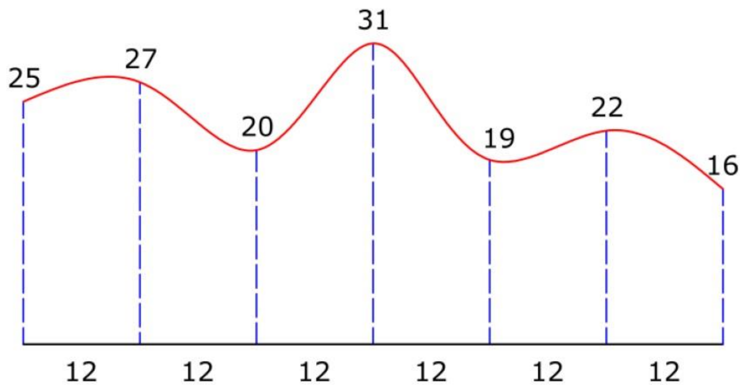
Method: Average

$$A = \left(\frac{7 + 16 + 20 + 9 + 13 + 23 + 8 + 12}{8}\right) * 70 = 945\ m^2$$

Trapezoidal Method:

$$A = 10\left(\frac{7 + 12}{2} + 16 + 20 + 9 + 13 + 23 + 8\right) = 985\ m^2$$

Example: Find the area of the Fig. below by using (Simpsons Rule).



$$A = \frac{12}{3}[(25+16)+4(27+31+22)+2(20+19)] = 1736\ m^2$$

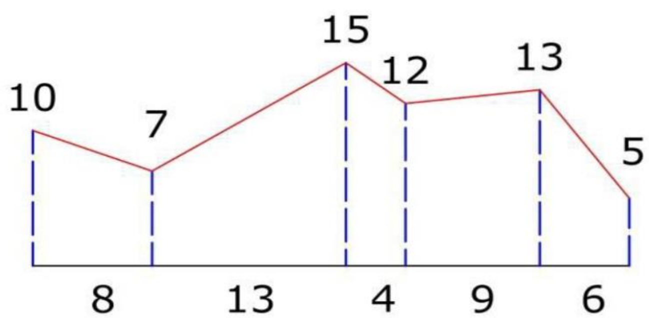
Setting out Offset at Irregular Intervals

This method is applied in cases where it is not possible to install columns at equal distances due to the terrain characteristics or the presence of physical obstacles. The governing formula for this method can be stated as follows:

$$2A = d_1(h_1 - h_3) + (d_1 + d_2)(h_2 - h_4) + (d_1 + d_2 + d_3)(h_3 - h_5) + (d_1 + d_2 + d_3 + d_4)(h_4 - h_6) + (d_1 + d_2 + d_3 + d_4 + d_5)(h_5 - h_7) + (d_1 + d_2 + d_3 + d_4 + d_5 + d_6)(h_6 + h_7)$$

$$\left|\frac{\mp X}{2}\right| = A$$

Find the area of the fig. Below by using Appropriate Method



$$2A = 8(10-15) + (8+13)(7-12) + (8+13+4)(15-13) + (8+13+4+9)(12-5) + (8+13+4+9+6)(13+5)$$

$2A = 863$, $A = 431.5\ m^2$

Overview

A –Target population :-

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B –Rationale :-

The motivation for teaching the coordinate method and the D.M.D method is to equip students with precise tools for calculating areas of irregular plots. These methods enhance accuracy and efficiency in land surveying tasks.

C –Central Idea :-

1. Introduction to the coordinate method for area calculation.
2. Learning the D.M.D (Double Meridian Distance) method.
3. Applying both methods to accurately measure irregular land areas.

D – Performance Objectives

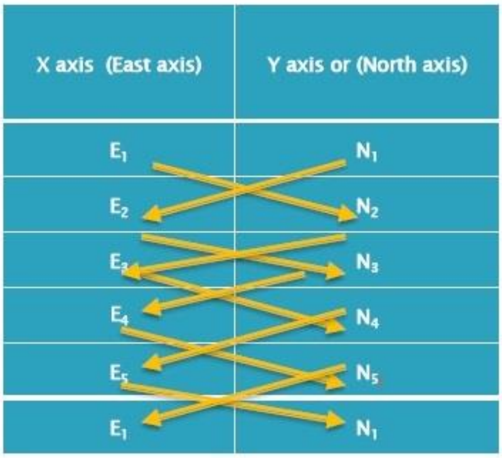
1. Students will explain the principles of the coordinate method for area calculation.
2. Students will apply the D.M.D method to find areas of irregular plots.
3. Students will accurately compute land areas using both coordinate and D.M.D methods.

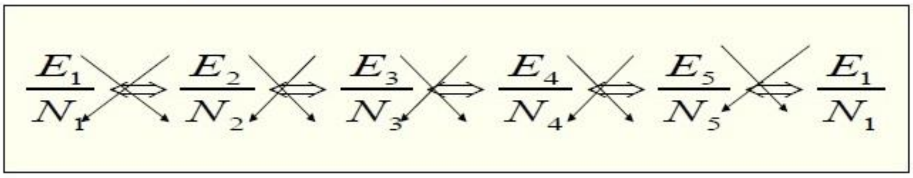
Area Measurement Using Coordinates

If the corners of the boundaries of a closed plot of land are known, then it is possible to calculate twice the area of that plot by using the coordinate law.

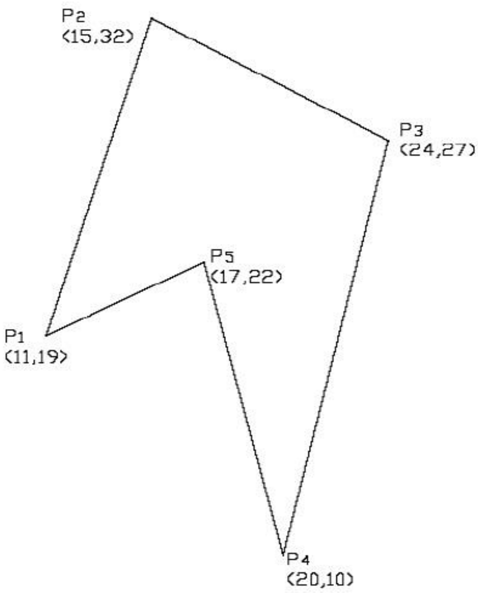
Twice the area = the algebraic sum of the product of the x-coordinate (dispersal coordinate) for each point * the difference of the y-coordinate (inclusion coordinate) for the points before and after that point.

Note: - It starts from a certain point and in a certain direction until returning to the same point (the starting point).





Example: from corrected coordinates for a closed traverse is shown in figure bellow. Calculate the area of land by using coordinates rule.



$$2A = [(19 * 15) + (32 * 24) + (27 * 20) + (10 * 17) + (22 * 11)] - [(11 * 32) + (15 * 27) + (24 * 10) + (20 * 22) + (17 * 19)]$$

$$A = \left|\frac{245}{2}\right| = 122.5\ m^2$$

Using Double Meridian Distance Method (DMD)

This method is used when the horizontal and vertical components of the sides of the polygon are known and it may be called the composite method.

- Meridian distance for point = the distance of the point from the north line.
- Meridian distance for line = the distance of the midpoint of the line from the north axis.
- Double the distance of the longitude of the (Double-meridian-Distance for line) line = is the sum of the distances of the starting and ending points of that line from the north axis.

The formula for calculating twice the area of the general longitude is:

D.M.D الضلع **= Dep** الضلع السابق **+ D.M.D** الضلع السابق **+ Dep** الضلع نفسه

So the law for the first side becomes

D.M.D = Dep of the first side

The last side is:

Last leg D.M.D = – Dep

Rules for calculating area by methods (DMD)

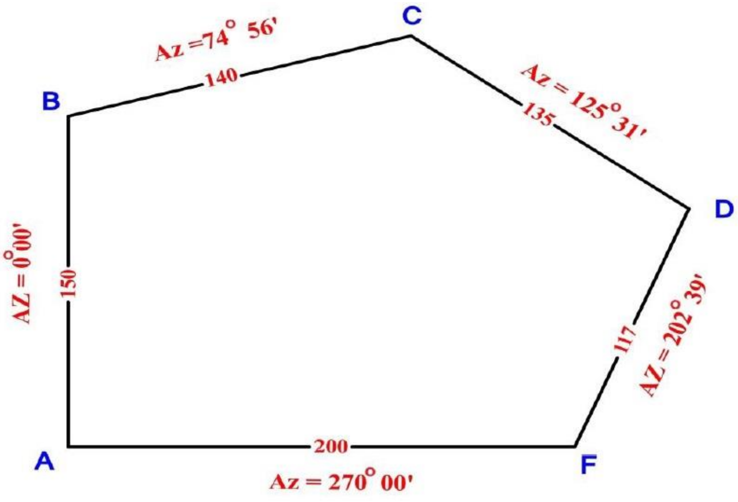
1. Find twice the longitude distance of the first side (DMD) = the horizontal component of the side.
2. Find twice the longitude distance of any other side (DMD) = twice the longitude distance of the previous side +
3. The horizontal component of the previous side + the horizontal component of the present side.
4. Twice the longitude distance of the last side = - (the horizontal component of the other side).

Notes to verify work:

1. The sum of the vertical components of the sides of the polygon = zero.
2. The sum of the horizontal components of the sides of the polygon = zero.

3. Twice the longitude distance of the last side = - (the horizontal component of the last side).

Example: Find the area of the Fig. below by using DMD



given data			Required	
Side	Length (m)	AZ	Dep.	Lat.
AB	150	$0^\circ 00'$	0	150
BC	140	74° 56'	135.19	36.39
CD	135	125° 31'	109.88	-78.43
DE	117	202° 39'	-45.06	-107.98
EA	200	270° 00'	-200	0

Side	Dep.	DMD	Lat.	2A
AB	0	0	150	0
BC	135.19	135.19	36.39	4919.56
CD	109.88	380.26	-78.43	-29823.80
DE	-45.06	445.08	-107.98	-48059.74
EA	-200	200	0	0
$\sum$	0	----	0	-72962

$$A = \left|\frac{-72964}{2}\right| = 36482\ m^2$$

Overview

A –Target population :-

Second-Year Students
Technological Technical Institute in Basra
Department of Surveying Technologies

B –Rationale :-

Teaching area calculation by dividing land into regular geometric shapes and calculating cross-sections of roads helps students simplify complex measurements. These skills are essential for effective land surveying and road design.

C –Central Idea :-

1. Understanding land area calculation by dividing it into regular geometric shapes.
2. Learning to calculate cross-sections of roads accurately.
3. Applying these methods in practical surveying and engineering projects.

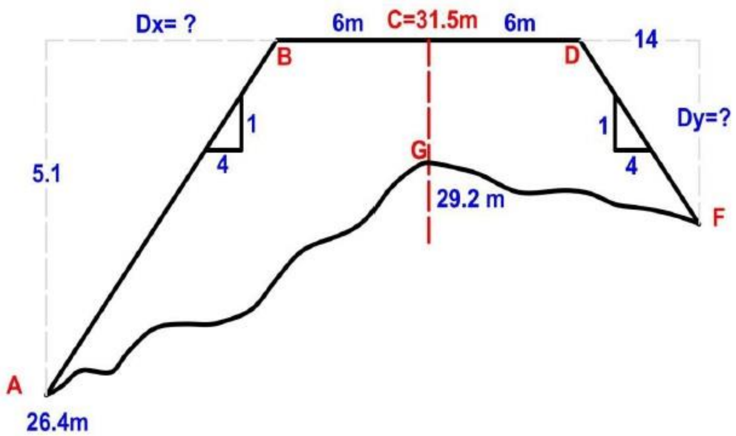
D – Performance Objectives

1. Students will divide irregular land into regular shapes for area calculation.
2. Students will compute cross-sectional areas of roads.
3. Students will apply these techniques in practical field measurements and design.

Area of cross section

- The longitudinal section of a land surface along the central line obtaining by using the longitudinal leveling process، where the levels calculated at intervals of every 100 m, and they are usually called stations, chains, or distances. Then the longitudinal section of the landline is drawn and called (Ground Line). Then draws in the profile the longitudinal section of the construction line called (Grade Line).
- After that, we take the cross sections, which are perpendicular to the longitudinal section using the Cross-section levelling process. Cross-section- levelling Calculates the levels of points on either side of the centerline for short distances, especially in the changes in the nature of the land, it is calculated for each full station per 100 m. If necessary, and when the terrain changes, the settlement between the full stations is used, and it is called partial stations, then the cross-sections of the full stations and the partial stations are drawn.

Example: Find the Missing (Elevation & Horizontal Distance) for the fig. Below, if the side slope (1:4).



Elev. Of point (F)

$$\frac{1}{4} = \frac{Dy}{14} \rightarrow Dy = 3.5\ m$$

Elev. Of point (F) =31.5-3.5 =28 m

Dist. (Dx) from point (A)

$$\frac{1}{4} = \frac{5.1}{Dx} \rightarrow Dx = 20.4\ m$$

Dist. From (A) to center line =6+20.4 =26.4 m

The coordinates:

A(0,26.4), B(20.4,31.5), C(26.4,31.5), D(32.4,31.5), F(46.4,28), G(26.4,29.2)

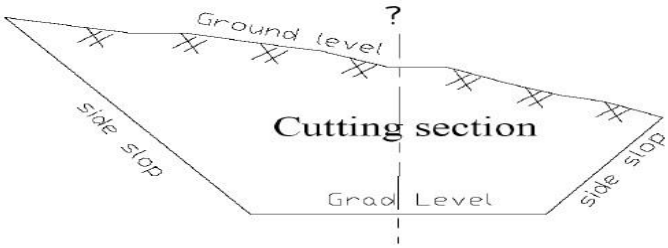
The cross-sections are of three main forms:

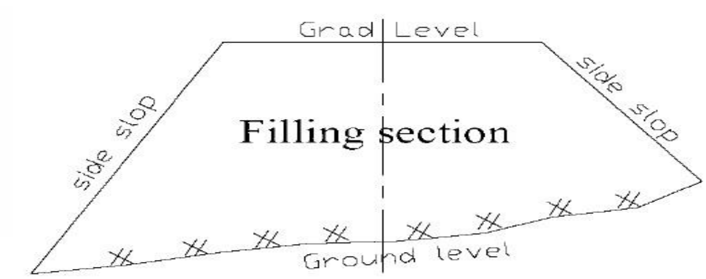
i. Cutting section

Where the ground level is higher than the graduate level.

ii. Filling section

Where the ground level is lower than the graduate level



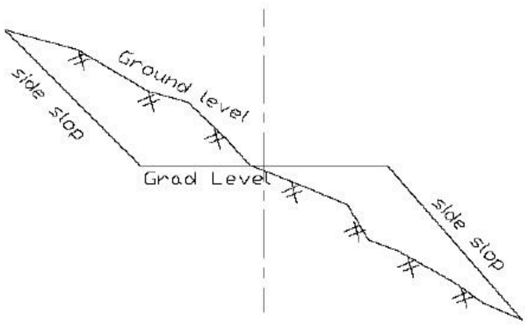


iii. Side–Hill section

Where the ground level is higher than the graduate level on one side and lower than it on the other.

Side slop is known for any cross section the ratio between the units of the vertical distance to the unit of the horizontal distance and usually write

$$\frac{1}{s} \ or \ 1{:}s$$

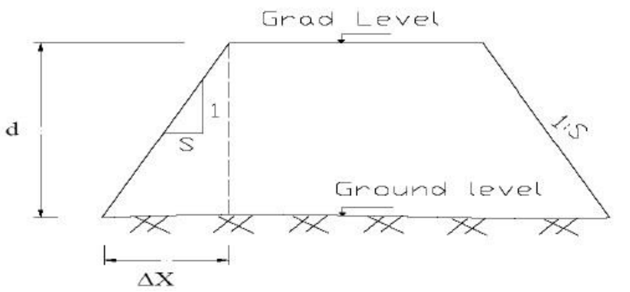


A. For a level section computation

d = (Ground Level – Grad Level)

d = + then depth of cut

d = – then depth of fill



$$\frac{1}{s} = side\ slop$$

$$A = d(b + s.d)$$

B. For a three level section computation

b/2= half of grad line.

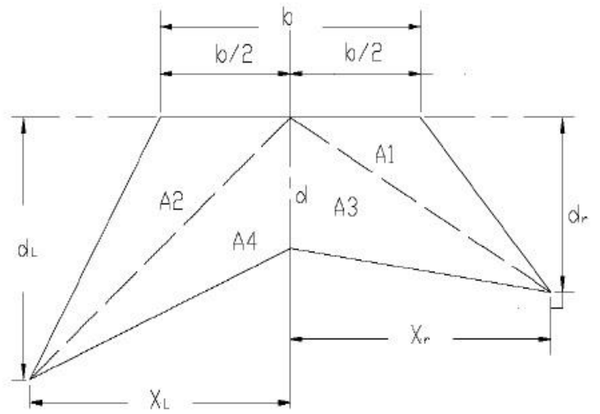
d = depth of cut or fill.

d_r =depth of cut or fill to the right side.

d_l = depth of cut or fill to the left side.

x_r = horizontal distance from ℄ to the point of right side.

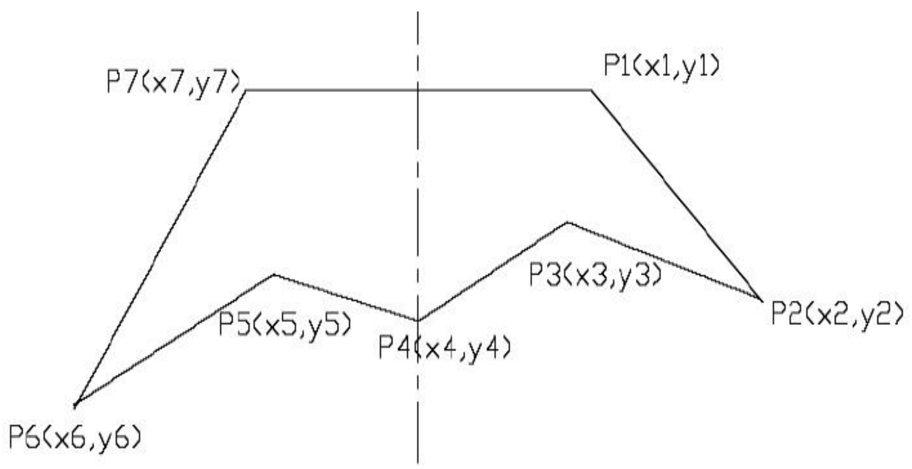
x_l = horizontal distance from ℄ to the point of left side



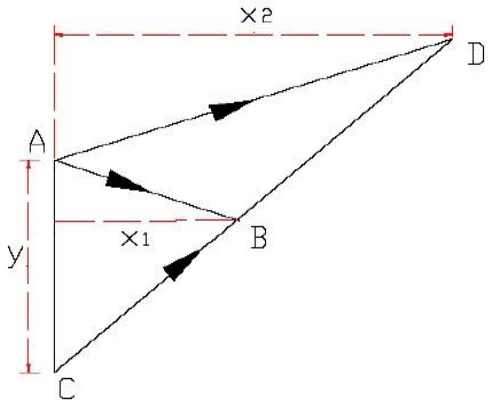
$$A = \frac{1}{2} * [\frac{b}{2}(d_r + d_l) + d(x_r + x_l)]$$

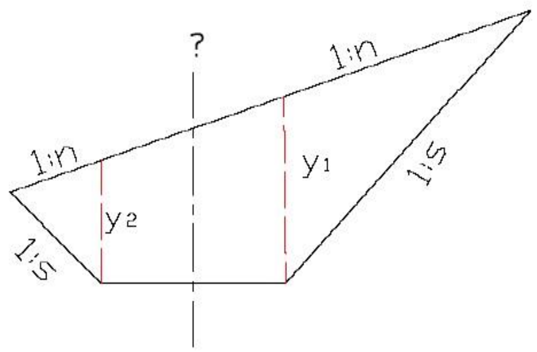
C. For a multi-level section computation

$$2A = \frac{x_1}{y_1} \times \frac{x_2}{y_2} \times \frac{x_3}{y_3} \times \frac{x_4}{y_4} \times \frac{x_5}{y_5} \times \frac{x_6}{y_6} \times \frac{x_7}{y_7} \times \frac{x_1}{y_1}$$



D. Computation a cross section if known a side slope for the ground





Calculated by the rate of approach

If we get the height (y) and the two miles as in the triangle ABC, the distance x1 can be calculated, which is calculated by summing the two miles, then flipping the result and multiplying it by the value of y.

When the two slopes are in opposite directions, as in the triangle ABC، we add the two slopes as in the following equation

$$(\frac{1}{s}+\frac{1}{n})^{-1} * y = x_1$$

When the two slopes are in the same direction as in the triangle ACD, we subtract the two slopes as in the following equation

$$(\frac{1}{s}-\frac{1}{n})^{-1} * y = x_2$$

Then we calculate the area of the triangles and the area of the trapezoid and add them to get the area of the cross section

Overview

A –Target population :-

Second-Year Students
Technological Technical Institute in Basra
Department of Surveying Technologies

B –Rationale :-

Teaching earthwork volume calculation enables students to estimate the amount of soil to be excavated or filled accurately. This skill is crucial for construction planning and cost estimation.

.

C –Central Idea :-

1. Introduction to methods for calculating earthwork volumes.
2. Understanding excavation and fill volume concepts.
3. Applying volume calculations in construction and land development projects

D – Performance Objectives

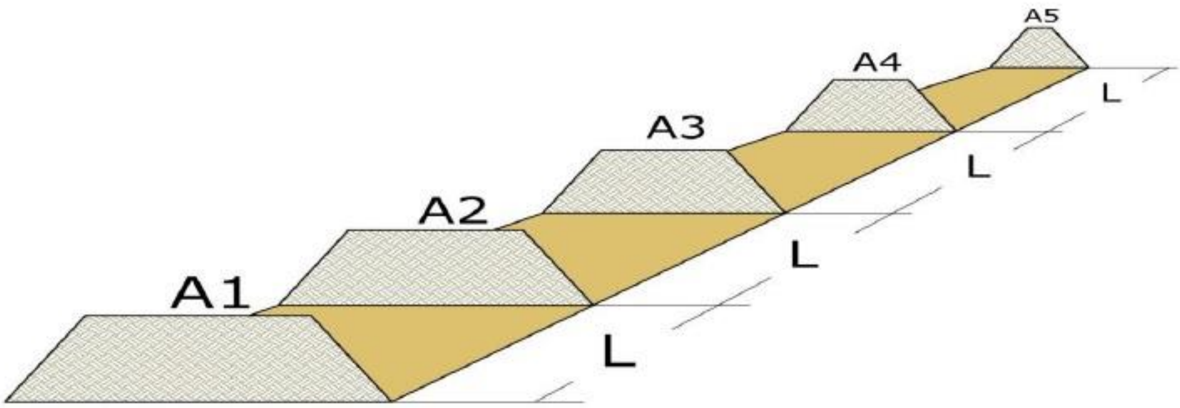
1. Students will explain the principles of earthwork volume calculation.
2. Students will calculate volumes of excavated and filled soil accurately.
3. Students will apply volume estimation techniques in practical engineering scenarios

Volumes

Just as there are various methods for measuring areas، the processes of finding earth volumes vary according to the previous measurement methods, as well as the nature of the land for which earth volumes are required to be calculated. The process of calculating earth volumes for roads is different from those volumes that are calculated for depressions and heights that can be represented by contour lines.

1. Area formula-average end

As shown in the figure below. The size of the road section is calculated using the following relationship:



$$V = L(\frac{A_1 + A_n}{2} + A_2 + A_3 + \ldots\ldots + A_{n-1})$$

This method is used if the spaces between the stations change, where the segment whose period changes are taken and calculated individually as in the following relationship:

$$V = L(\frac{A_1 + A_2}{2})$$

2. Prismoidal formula

It is used in the event that the number of syllables is odd (3, 5, 7 ......) and its mathematical relationship is similar to (Simpson's rule) to be used in calculating areas.

$$V = \frac{L}{3}[(A_1 + A_n) + 4(A_2 + A_4 + \ldots\ldots + A_{n-1}) + 2(A_3 + A_5 + \ldots\ldots + A_{n-2})]$$

Example: For the data below, find the total volume of (Cut & Fill) by using average & Prismoidal methods

St.	Area (m^2)		Vol. (m^3)	
	Cut	Fill	Cut	Fill
5+00	12			
6+00	16			
7+00	22			
8+00	9			
9+00	6		6/3*100 = 200	15/3 *100 = 500
10+00		15		
11+00		19		
12+00		21		
13+00		24		

- For cut
- By Avg.-end method

$$V\ of\ cut = 100[\frac{12+6}{2} + 16 + 22 + 9)] = 5600\ m^3$$

$$total\ V\ of\ cut = 5600 + 200 = 5800\ m^3$$

- By Prismoidal formula

$$V\ of\ cut = \frac{100}{3}[(12+6) + 4(16+9) + 2(22)] = 5400\ m^3$$

$$total\ V\ of\ cut = 5400 + 200 = 5600\ m^3$$

- For fill
- By Avg.-end method

$$V = 100\left[\frac{15+24}{2} + 19 + 21\right] = 5950 + 500 = 6450\ m^3$$

- By Prismoidal formula (6-8)

$$V = \frac{100}{3}[(15+21) + 4(19)] = 3730\ m^3$$

Vol. of fill (8-9)

$$V = 100\left[\frac{21+24}{2}\right] = 2250\ m^3$$

$$total\ V\ of\ fill = 3730 + 2250 + 500 = 6480\ m^3$$

Overview

A –Target population :-

Second-Year Students
Technological Technical Institute in Basra
Department of Surveying Technologies

B –Rationale :-

Teaching vertical curves in road design helps students understand smooth transitions between different road grades. Calculating and plotting these curves is essential for safe and efficient road construction

.

C –Central Idea :-

1. Understanding types of vertical curves in road design.
2. Learning how to calculate the elevations (grades) of vertical curves.
3. Mastering the methods for plotting (staking out) vertical curves on the field

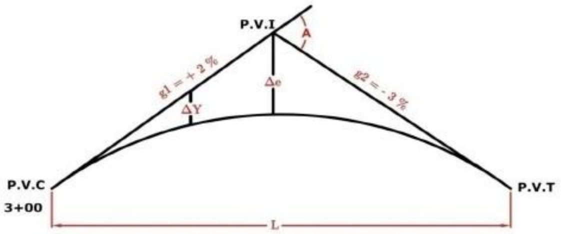
D – Performance Objectives

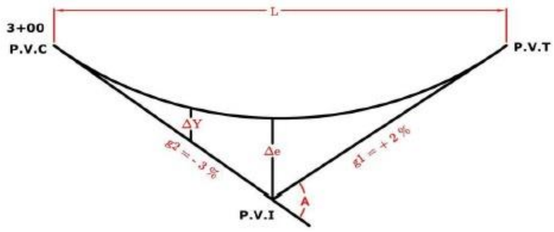
1. Students will identify and describe different types of vertical curves.
2. Students will calculate the elevations and gradients of vertical curves accurately.
3. Students will demonstrate the ability to stake out vertical curves in practical exercises

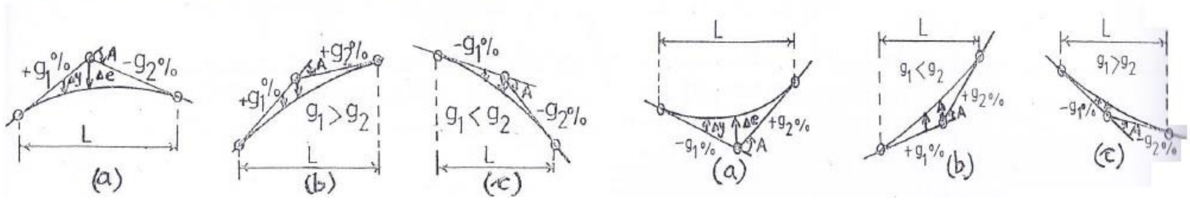
Vertical curves

Steps of rout surveying

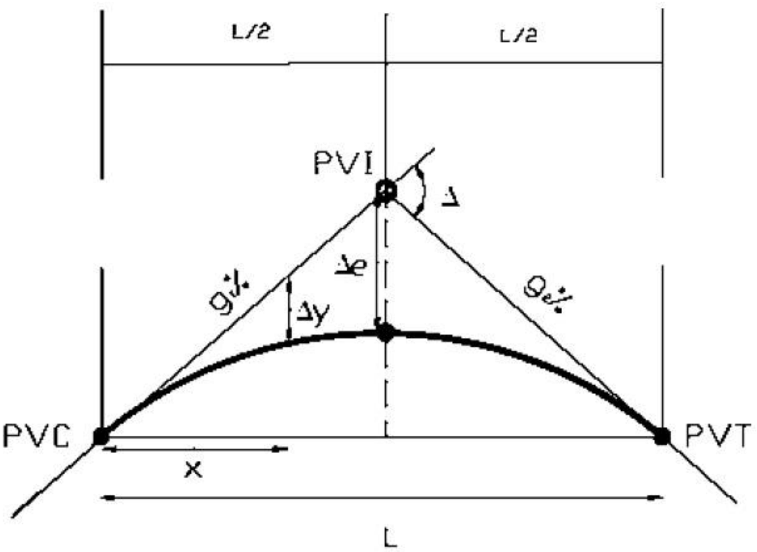
- Reconnaissance
- Preliminary survey.
- Location survey.
- Construction survey







Using to connected two lane have changeable gradient in the vertical level, that to using gradual change in vertical movement.



- g1, g2: percent grade
- L: length of vertical curve
- r: rate of change of grade per station
- Δy: difference in elevation between tangent & curve
- Δe: difference in elevation at P.V.I
- A: Algebraic difference in grade

- P.V.C: Point of Vertical Curvature
- P.V.I: Point of Vertical Intersection
- P.V.T: Point of Vertical Tangency

$$A = g_2 - g_1$$

$$r = \frac{A}{L}$$

$$\Delta y = \frac{r}{2} * x^2 \text{ ,where x is the distance of station from start or end}$$

$$\Delta e = \frac{A * L}{8}$$

$$elev.P.V.I = elev.P.V.C \mp \frac{g_1}{100} * \frac{L}{2}$$

$$elev.P.V.T = elev.P.VI \mp \frac{g_2}{100} * \frac{L}{2}$$

$$st.P.V.I = st.P.V.C + \frac{L}{2}$$

$$st.P.V.T = st.P.V.I + \frac{L}{2}$$

or

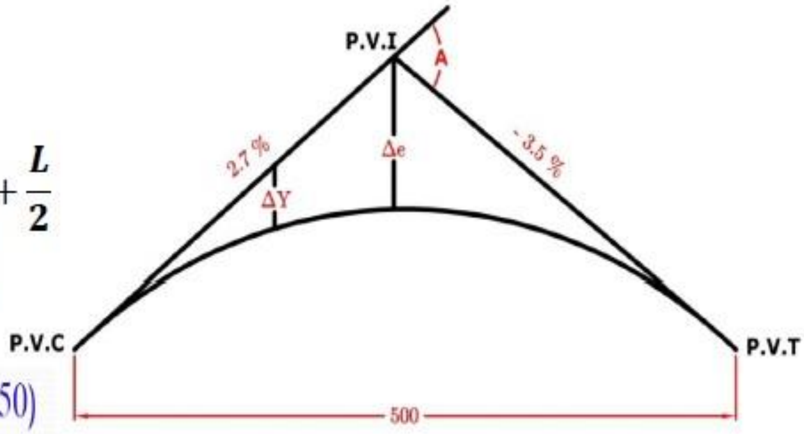
$$st.P.V.T = st.P.V.C + L$$

Computation Methods of Vertical Curve:-Engineering Methods

Using difference elevation dependent on (r) value:

1. Calculate the P.V.T, P.V.I, P.V.C terminals with their levels
2. Calculate the value of Δe, r/2,r, A،
3. Plan a table in which stations and levels are placed, as shown in the figure
4. The stations are divided according to what is required
5. Calculate the levels of the points on the first tangent using the g1 plane, PVC and the distances between the starting point and other points in the direction of P.V.I
6. The levels of the points on the second tangent are calculated using the g2 ratio, P.V.T and the distances are calculated from P.V.T towards P.V.I

Ex : compute the elevation of main & full stations on vertical curve , if the station P.V.I = 34+20 , L= 500 m, Elevation
P.V.I = 31.70 m.



Sol: (1)

$$St.P.V.I = St.P.V.C + \frac{L}{2}$$

$$St.P.V.C = St.P.V.I - \frac{L}{2}$$

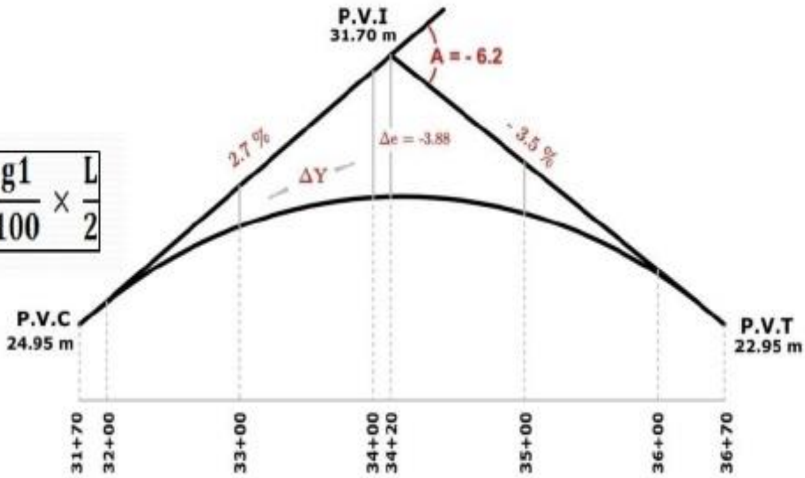
→ St. P.V.C = (34+20) – (2+50)

St. P.V.C = (31+70) .

(b) St. P.V.T = St. P.V.I + (L/2) → St. P.V.T = (34+20) +(2+50)

(2) a :

$$elev.P.V.I = elev.P.V.C \pm \frac{g1}{100} \times \frac{L}{2}$$



elev. P.V.C = elev. P.V.I - (g1 / 100)x(L/2)
elev. P.V.C = 31.7- (2.7/100)x(250) elev.
P.V.C = 24.95 m

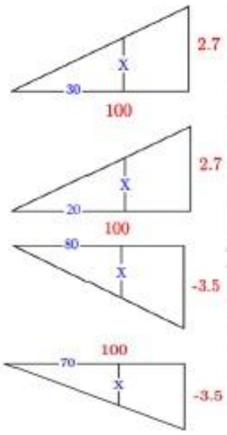
b : $$elev.P.V.T = elev.P.V.I \pm \frac{g2}{100} \times \frac{L}{2}$$

elev. P.V.T = 31.70-(3.5/100)x(250)
elev. P.V.T = 22.95m

(3) A = g2−g1 = (−3.5) − (+2.7) = −6.2

(4) r=A/L = −6.2/5 = −1.24

(5) Δe = A×L/8 = −6.2x5/8 = −3.88m



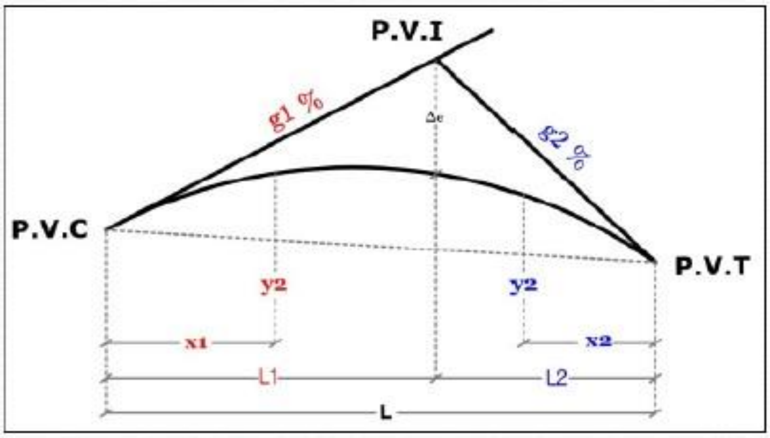
Station	Tangent Elev. (m)	$\Delta y = (r/2)\times X^2$	Curve Elev.(m)
P.V.C. 31+70 محسوب	24.95 محسوب	0.00	24.95
	(+2.7/100) ×30 = +0.81	-1.24 / 2	
32+00	25.76 +	Δy = -0.62 ×(0.3)² = -0.06 =	25.70
	(+2.7/100)×100 = +2.7		
33+00	28.46	Δy = -0.62×(1.3)² = - 1.05	27.41
	(+2.7/100)×100 = +2.7		
34+00	31.16	Δy = - 0.62×(2.3)² = - 3.28	27.88
	(+2.7/100)×20 = +0.54	Δy = - 0.62×(2.5)² = - 3.88	
P.V.I. 34+20 معطى	31.70 معطى	-3.88 (To check)	27.82
		Δy = -0.62×(2.5)² = - 3.88	
	(-3.5/100)×80 = -2.8		
35+00	28.90	Δy = -0.62×(1.7)² = -1.79	27.11
	(-3.5/100)×100 = -3.5		
36+00	25.40 +	Δy = -0.62×(0.7)² = -0.30 =	25.10
	(-3.5/100)×70 = -2.45		
P.V.T. 36+70 محسوب	22.95 محسوب	0.00	22.95

Unsymmetrical curve vertical:

$$\Delta e = \frac{g_2 - g_1}{2L} \times l_1 \times l_2$$

$$r_1 = \frac{g_2 - g_1}{L} \times \frac{l_2}{l_1}$$

$$r_2 = \frac{g_2 - g_1}{L} \times \frac{l_1}{l_2}$$



$$Elev.P.V.C = Elev.P.V.I \pm \frac{g_1}{100}(l_1)$$

$$Elev.P.V.T = Elev.P.V.I \pm \frac{g_2}{100}(l_2)$$

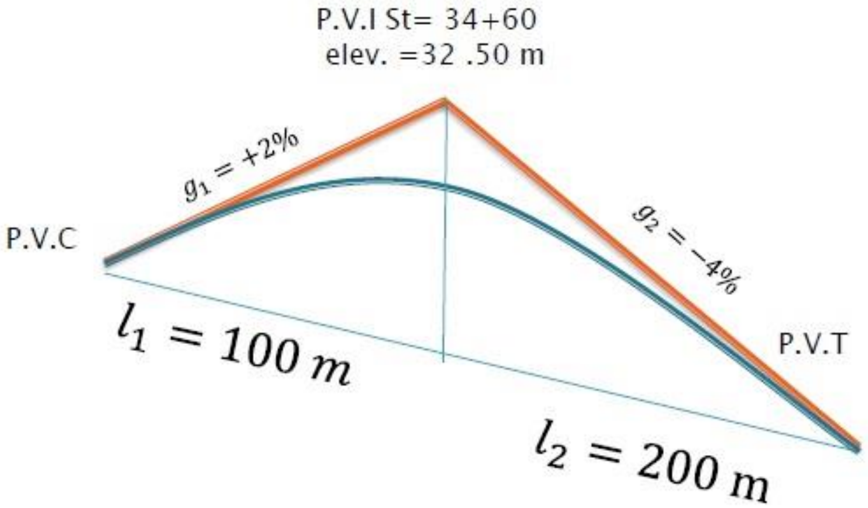
$$y_1 = Elev.P.V.C + g_1(x_1) + \frac{r_1}{2}(x_1)^2$$

$$y_2 = Elev.P.V.T \ominus g_2(x_2) + \frac{r_2}{2}(x_2)^2$$

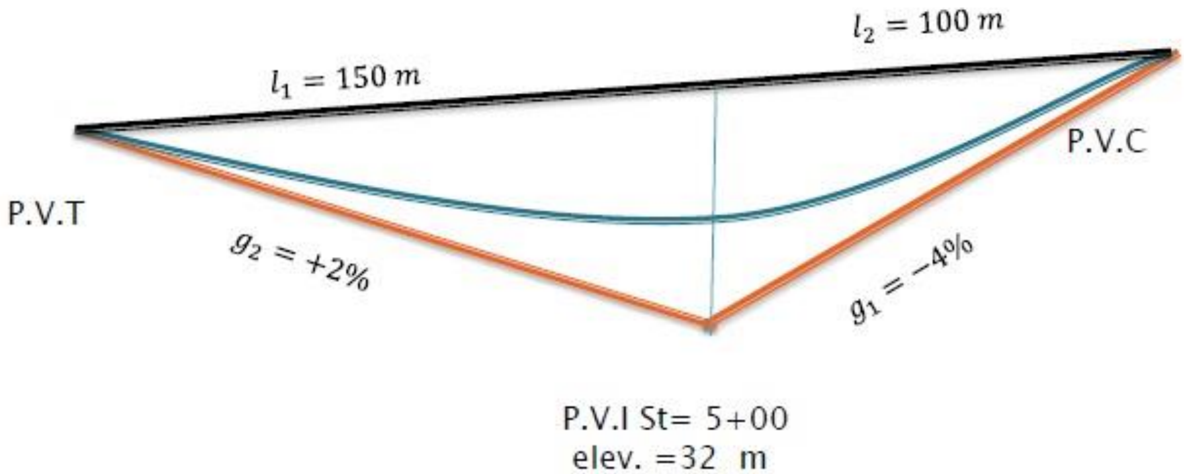
Note: The sign surrounded by a circle above was placed in the negative direction because the calculations are in the direction of the left.. That is, the point whose level is required to be found has a negative slope (-g2) In order to obtain an increase from the point (P.V.T), a negative sign must be placed for an object attributed to (y), so it increases with respect to (P.V.T). In other words، this The reference depends on the desired affiliate site

$$St.P.V.C = St.P.V.I - L1 \qquad St.P.V.T = St.P.V.I - L2$$

H.W1: calculate the elevations of the half stations for the asymmetric vertical curve shown below using the analytical method



H.W: calculate the elevations of the half stations for the non-symmetric vertical curve shown below using the geometric method, and then find the station and elevation of lowest point of it



Overview

A –Target population :-

Second-Year Students
Technological Technical Institute in Basra
Department of Surveying Technologies

B –Rationale :-

Teaching horizontal curves in road design enables students to plan safe and efficient road alignments. Understanding their equations and calculations of stations and coordinates is critical for precise field layout

.

C –Central Idea :-

1. Understanding types of horizontal curves used in road design.
2. Learning equations and calculations for horizontal curves.
3. Calculating stations and coordinates of curve points for accurate field implementation.

D – Performance Objectives

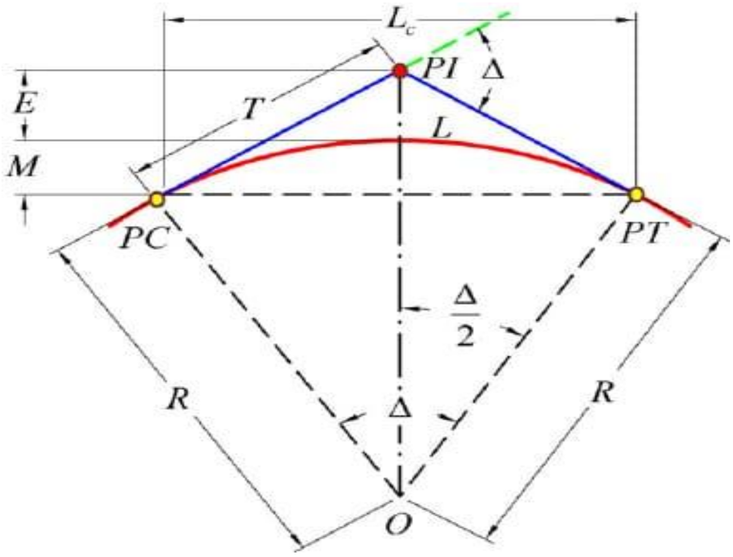
1. Students will identify different types of horizontal curves in roadways.
2. Students will apply equations to calculate curve parameters accurately.
3. Students will compute stations and coordinates of key curve points for surveying

Horizontal curve

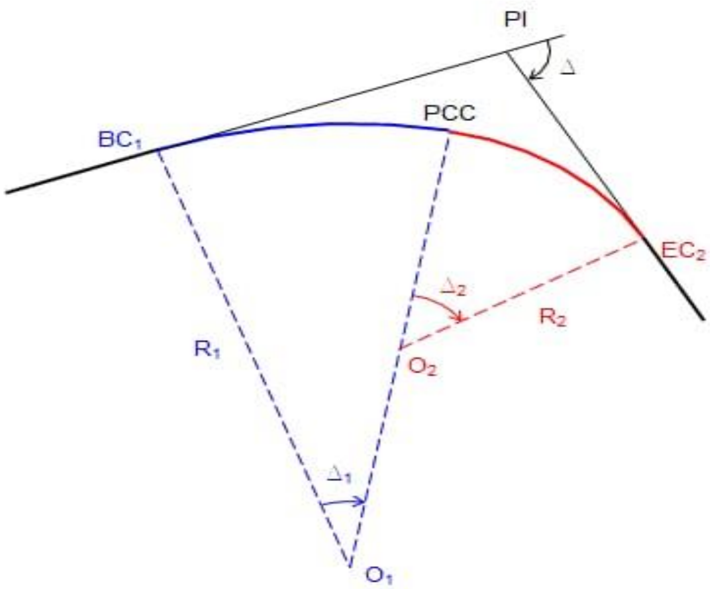
Circular Curve

Horizontal curves are used to connect two paths associated with an angle, with the aim of changing turn right or left at the horizon level gradually.

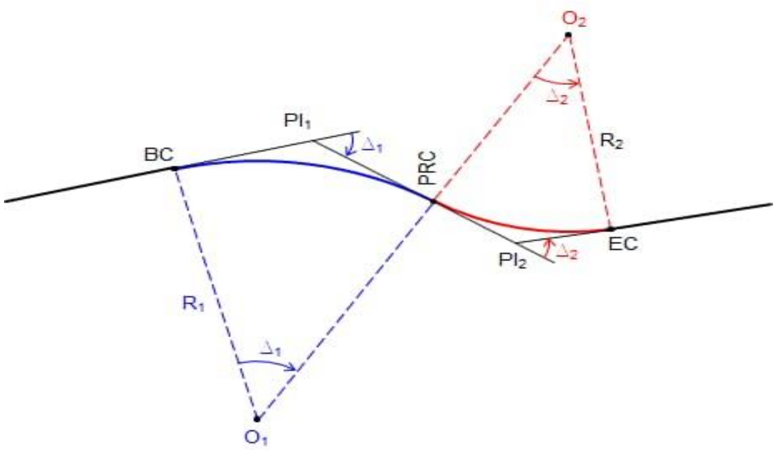
a) Simple circular curve: is the most basic type of horizontal curve and is widely used in highway and railway design. It consists of a single arc of a circle and is defined by a constant radius throughout the curve.



b) Compound circular curve: is a type of horizontal curve in roadways, railways, and other alignment designs where two or more simple circular curves of different radii are connected without a straight section (tangent) between them, sharing a common tangent at the point of junction.



c) Reverse circular curve: also called an S-curve is a horizontal curve consisting of two simple circular arcs with equal or different radii, bending in opposite directions, and connected directly without an intervening tangent.



Symbols and Characters:

P.I. = Point of Intersection {V. (Vertex)}

P.C. = Point of Curvature {B.C. (Beginning of Curve)}

P.T. = Point of Tangency {E.C. (End of Curve)}

T. = Tangent Length

D. = Deflection Angle {Intersection Angle}

R. = Radius of Curve

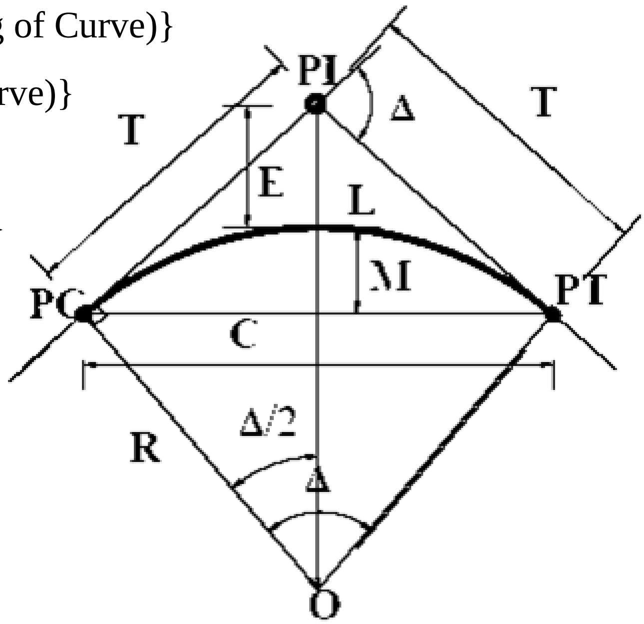
C. = Chord Length

L. = Length of Curvature

E. = External Distance

M. =Middle Distance

D = Degree of Curvature (Degree of Curve)



$$E = R\left(\frac{1}{\cos\frac{\Delta}{2}} - 1\right) \qquad D = \frac{573}{R_{(m)}}$$

$$L = \frac{\pi . R . \Delta}{180} \text{ or } \frac{10\Delta}{D} \qquad T = R\tan\frac{\Delta}{2}$$

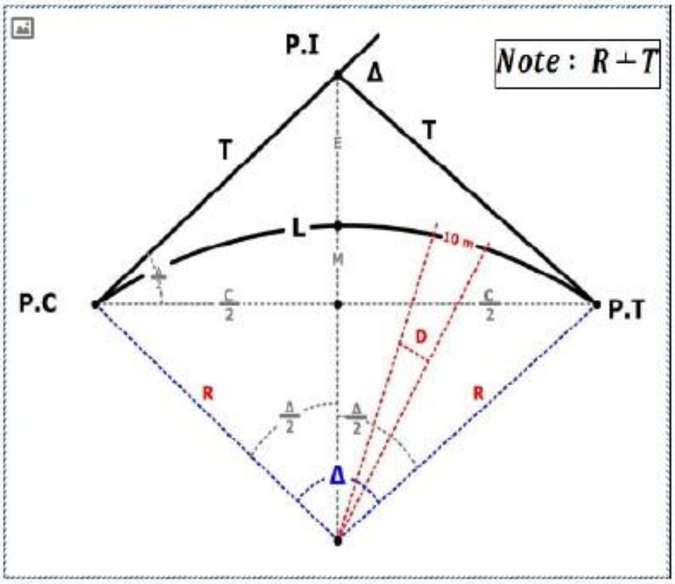
$$M = R\left(1 - \cos\frac{\Delta}{2}\right) \qquad C = 2R\sin\frac{\Delta}{2}$$

ملاحظة : E دائما اكبر من M

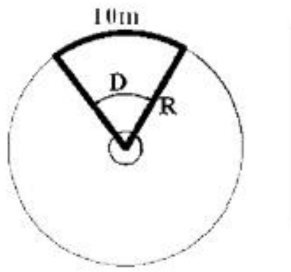
$$Sta.P.T = Sta.P.C + L$$

$$Sta.P.C = Sta.P.I - T$$

$$Sta.P.T = Sta.P.I - T + L$$



$$\frac{10}{D} = \frac{2\pi R}{360} = \frac{L}{\Delta}$$ ---------- (قياس الزوايا بالدرجات)



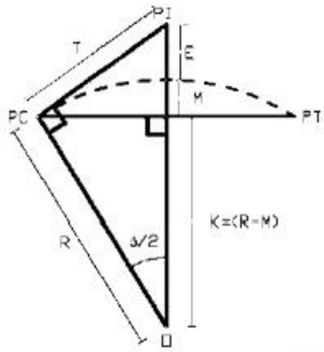
$L=\Delta.R$ (قياس الزاوية بالرديان) ------1a

$L=(10^{*}\ \Delta\ /D)$ (قياس الزوايا بالدرجات) -----1c

$L= \Delta.R\ ^{*}2\pi/360$ (قياس الزاوية بالدرجات) -----1b

$$R = \frac{10^{*}360}{D^{*}2\pi} = \frac{573}{D}$$ (قياس الزاوية بالدرجات)-----2a

$$D = \frac{573}{R}$$ (قياس الزاوية بالدرجات) -----2b



From triangle (PC. PI. O.)

$$\tan\frac{\Delta}{2} = \frac{T}{R}$$

T=R*tan(Δ/2) ------------- 3

From triangle (PC. P. O.)

$$\sin\frac{\Delta}{2} = \frac{C/2}{R}$$

C =2R*sin (Δ/2) -------------- 4

K = (R-M) $$\cos\frac{\Delta}{2} = \frac{K}{R}$$

K =R*cos(Δ/2)
R–M= R*cos(Δ/2)
M = R[1– cos(Δ/2)] ---------- 5

From triangle (PC. PI. O.)

$$\sec\frac{\Delta}{2} = \frac{(R+E)}{R}$$

R+E =R*sec(Δ/2)
E = R [sec(Δ/2)–1] -------------- 6

Note: - It is not permissible to calculate PT from (PI + T) because the length of the two tangents is not equal to the length of the curve.

$$2T > L > C$$

$$sta.\,PC = sta.\ PI - T$$
$$sta.\,PT = sta.\ PC + L$$

Example 1:-

A simple circular curve is to connect two tangent that intersection at angle Δ of 52° 36′ at station (14+80), radius of curve equal 250m.

Compute values of (C, L, T, M, E, D, PC and PT).

Solution:

$$\frac{10}{D} = \frac{2\pi R}{360} = \frac{L}{\Delta} \qquad L = \frac{\pi R}{180} 52°36'$$

$= 229.51m$

$D = 1800/\pi R = 573/250 = 2° \; 17' \; 31''$

$C = 2R*\sin(\Delta/2)$

$= 2*250*\sin 26°18' = 221.54m$

$T = R*\tan(D/2)$

$= 250*\tan 26°18' = 123.56m$

$E = R \; [\sec(\Delta/2) - 1]$

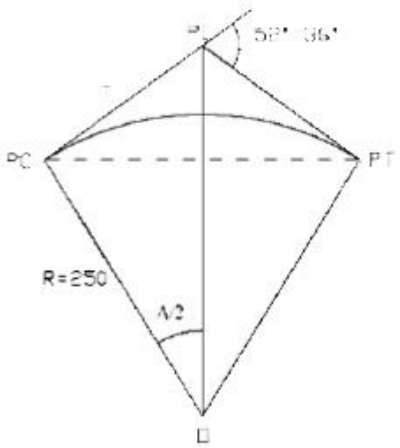
$= 250(\sec 26.3 - 1) = 28.87m$

$M = R \; [1 - \cos(\Delta/2)]$

$= 250(1 - \cos 26.3) = 25.88m$

$PC = PI - T = 1480 - 123.56 = 13+56.44$

$PT = PC + L = 1356.44 + 229.51 = 15+85.95$

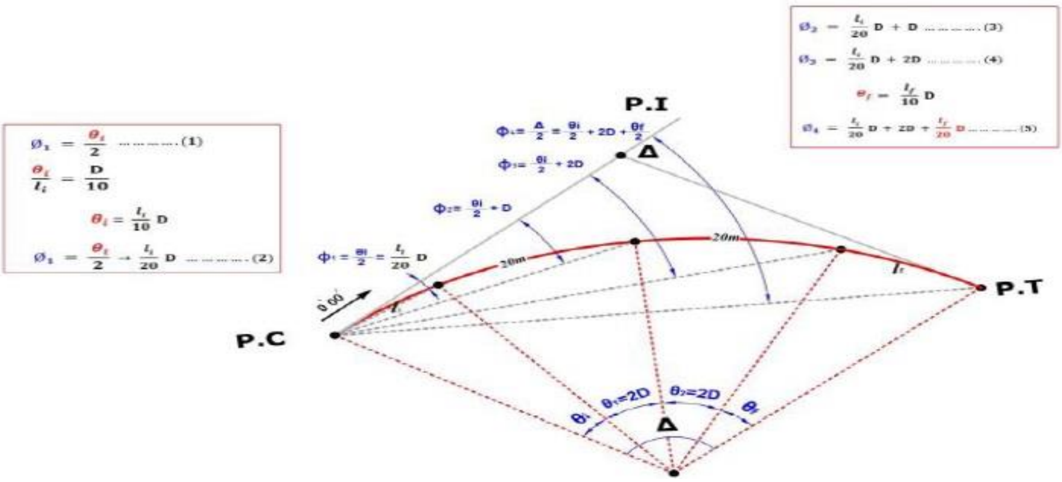


Tangential angles Method or Deflections Angles Method:

Projecting any point onto the ground requires determining both the distance and direction from a known reference point. If the target point is P.C, then projecting the curve points involves calculating the distance from P.C to the chord C, as well as determining the direction (Ø) to that point, measured from the tangent line.

And then assign the following stations for each (20m) until reaching the last station, which represents the remaining distance.

Calculating the angles of deviation (deflection) from the contact line, as shown in the following figure:



Furthermore, the values of • can be calculated from the above law. Thus, by the theodolite device, the points can be projected by horizontal angles, after pointing the device to the PI point, then the device is zeroed, after that we rotate the device according to the calculated α values.

$$d = l * \frac{D}{10} = l * \frac{360^\circ}{2\pi R} = l * \frac{573}{R}$$

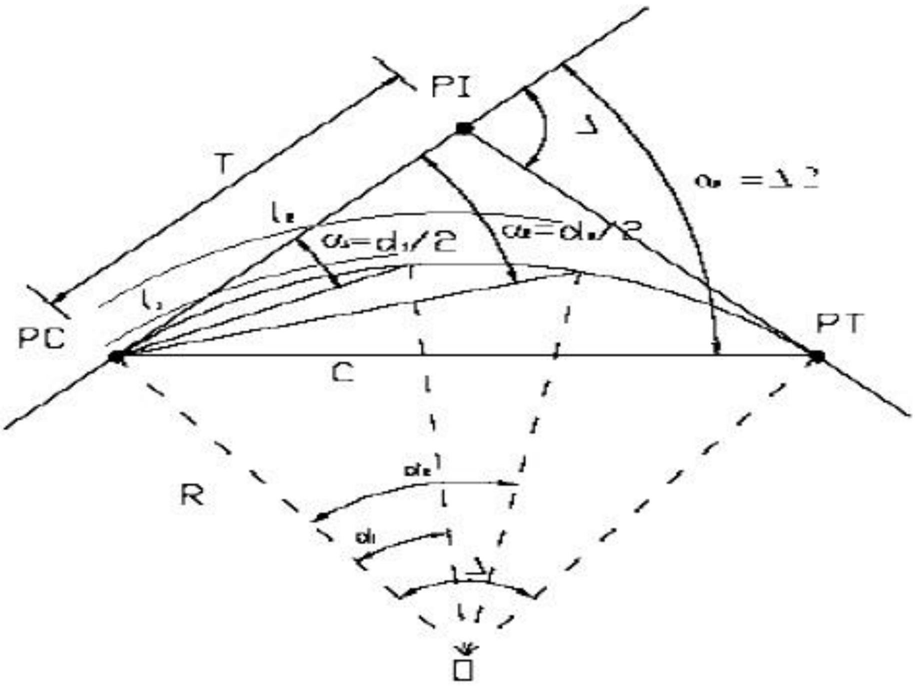
Central angle subtended by an arc of length (   )

$$\alpha = \frac{1}{2} d$$

The angle of deviation = ( ) the central angle corresponding to that arc

$$\alpha = l * \frac{D}{20}$$

The values of can be calculated from the above law. Thus, by the theodolite device, the points can be projected by horizontal angles, after pointing the device to the PI point, then the device is zeroed, after that, we rotate the device according to the calculated values.



The accounts:-

1. Compute the elements of the L, T, M, E, and C curves

2. Calculation of PC, PT, MC curve stations

3. Calculation of substations based on the division period

4. Calculate the distance of each station for the PC starting point

5. Calculate the tangent angle for each station, and the tangent angle for the last station should be Δ /2

6. Makes a chart of accounts

7. Projection at the site according to the angles fixed in the table.

Note: The period of the main stations must be mentioned, whatever the period of division

8. The theodolite device is installed on the PC point and directs the line of sight towards PI and the horizontal angle zeroes.

Note:

- If there is an obstacle towards PI, we start from PT and confirm the reading of the device (Δ/2), then we return to PI until we obtain an angle of ($00^{\circ}00'\,00''$), then we proceed to work, and to ensure the correctness of the work, we measure the distance between the PC And PT must be equal to the calculated value of T
- Distances are measured from the previous stations and are equal to the lengths of the arcs the following table shows the method of projecting a simple horizontal curve by tangent angles

Station	away from the previous point C	distance from the starting point l	$\alpha = l * \frac{D}{20}$	Notes
Sta. PC.	0	0	0	
:	:	:	:	
Sta. MC.		L/2		
:	:	:		
Sta. PT.		L	$\alpha = \frac{\Delta}{2}$	

Overview

A –Target population :-

Second-Year Students
Technological Technical Institute in Basra
Department of Surveying Technologies

B –Rationale :-

Teaching horizontal curve staking methods equips students with practical skills to accurately mark curves on the ground. Using both the offset (column) method and the intersection point method ensures versatility in fieldwork.

C –Central Idea :-

1. Understanding the principles of staking horizontal curves.
2. Learning the column (offset) method for curve staking.
3. Applying the staking from the intersection point method in practical surveys.

D – Performance Objectives

1. Students will explain the procedures for staking horizontal curves using different methods.
2. Students will perform curve staking using the column (offset) method accurately.
3. Students will apply the intersection point method to stake curves effectively in the field.

Tangential angles Method or Deflections Angles Method:

Projecting any point onto the ground surface requires two essential components: a distance and a direction, both measured from a known reference point. If point P.C is considered the required point, then projecting the curve points involves calculating the chord distance from point P.C. In addition, the direction to that point—denoted by the angle Ø—must also be determined. This direction is measured relative to the tangent (contact) line associated with the curve.

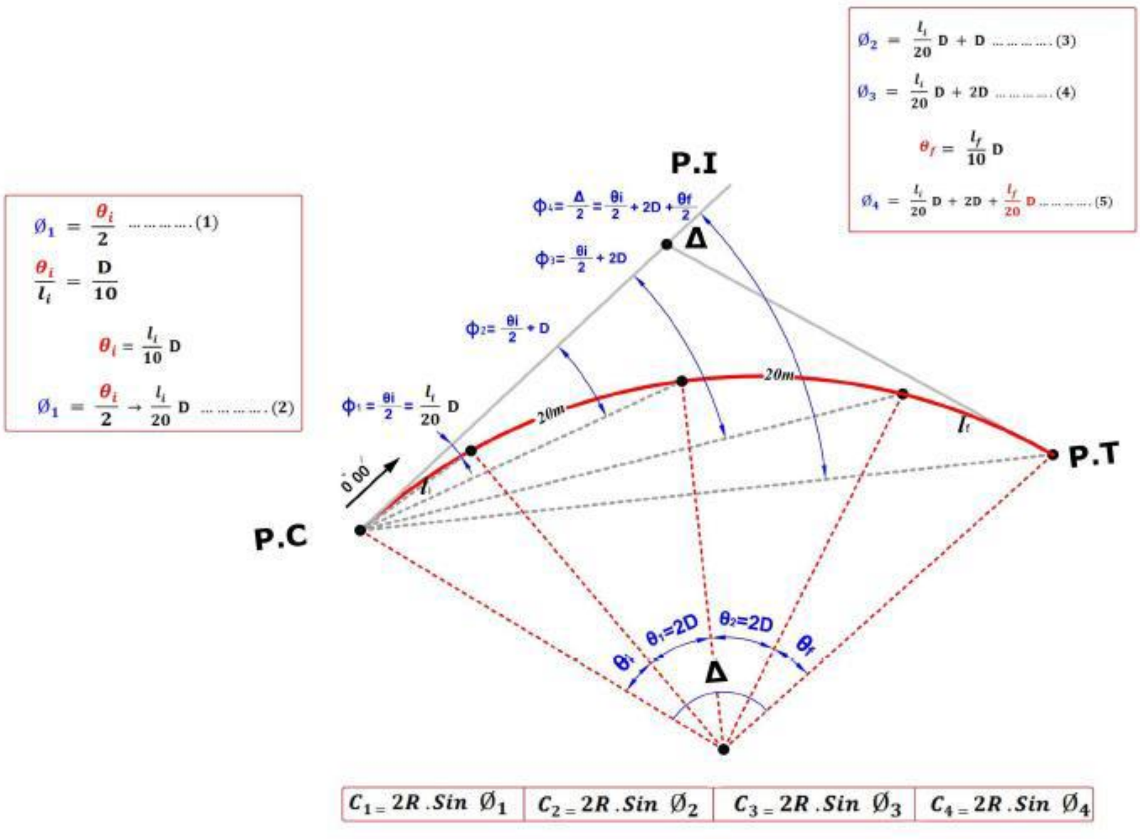
Steps to work in this way:

Determine the length of the first arc: it represents the distance that must be added to station P.C in order for the first station after station P.C to become a multiple of 20.

Example: $St.(P.C) = (15 + 25) \rightarrow First\ St. = (15 + 40)$

Then assign the following stations for each (20m) until reaching the last station, which represents the remaining distance.

Calculating the angles of deviation (deflection) from the contact line, as shown in the following figure:



Furthermore, the values of can be calculated from the above law. Thus, by the theodolite device, the points can be projected by horizontal angles, after pointing the device to the PI point, then the device is zeroed, after that, we rotate the device according to the calculated α values.

$$d = l * \frac{D}{10} = l * \frac{360}{2\pi R} = l * \frac{573}{R}$$

Central angle subtended by an arc of length ( )

$\alpha = \frac{1}{2}d$ The angle of deviation = ( ) the central angle corresponding to that arc

$$\alpha = l * \frac{D}{20}$$

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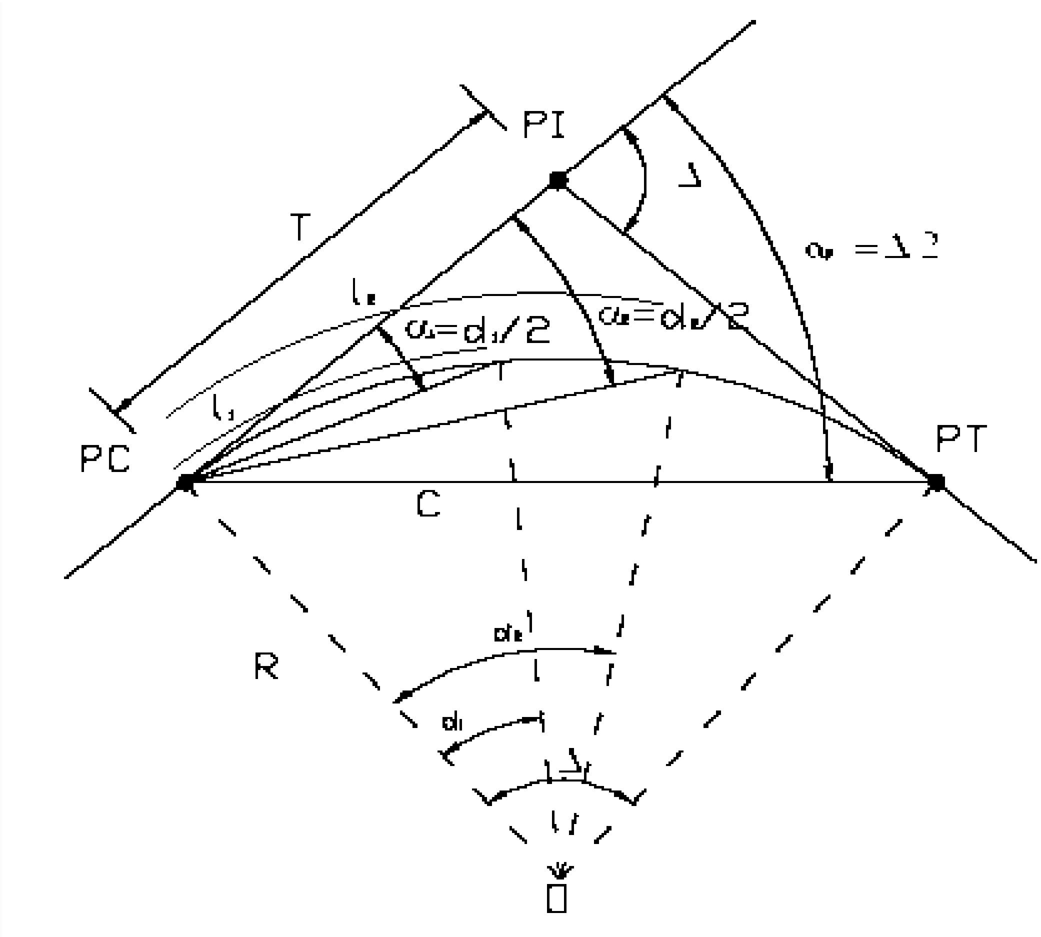


The accounts-:

1. Compute the elements of the L, T, M, E, and C curves

2. Calculation of PC, PT, MC curve stations

3. Calculation of substations based on the division period

4. Calculate the distance of each station for the PC starting point

5. Calculate the tangent angle for each station, and the tangent angle for the last station should be Δ /2

6. Makes a chart of accounts

7. Projection at the site according to the angles fixed in the table.

Note: The period of the main stations must be mentioned, whatever the period of division

8. The theodolite device is installed on the PC point and directs the line of sight towards PI and the horizontal angle zeroes

Note:

- If there is an obstacle towards PI, we start from PT and confirm the reading of the device (Δ/2), then we return to PI until we obtain an angle of (o 00' 00"0), then we proceed to work, and to ensure the correctness of the work, we measure the distance between the PC And PT must be equal to the calculated value of T
- Distances are measured from the previous stations and are equal to the lengths of the arcs. The following table shows the method of projecting a simple horizontal curve by tangent angles

Station	away from the previous point C	distance from the starting point l	$\alpha = l * \frac{D}{20}$	Notes
Sta. PC.	0	0	0	
:	:	:	:	
Sta. MC.		L/2		
:	:	:		
Sta. PT.		L	$\alpha = \frac{\Delta}{2}$	

Example: Setting out a simple circular curve by using a tangential angles method and length of (Total & single) chord, if you know:

D= 4° 48' , Δ = 45° 18' , St. P.I = 27+25

$$D = \frac{573}{R} \rightarrow R = \frac{573}{D} \rightarrow \frac{573}{4^o\ 48'} = 119.38\ m$$

$$T = R\tan\frac{\Delta}{2} = 119.38\ tan\ 22^o\ 39' = 49.82\ m$$

$$L = \frac{\pi R \Delta}{180} = \frac{\pi \times 119.38 \times 45^o\ 18'}{180} = 94.39\ m$$

$$C = 2R.\ Sin\frac{\Delta}{2} = 2 \times 119.38 \times Sin\ 22^o\ 39' = 91.95\ m$$

$$St.P.C = St.P.I - T = (27+25) - (0+49.82) = (26+75.18)$$

$$St.P.T = St.P.C + L = (26+75.18) + (0+94.39) = (27+69.57)$$

Station	Def. Angle	Total Chord (m) C = 2R Sin angle	Single Chord C = 2R Sin angle
P.C 26+75.18	$0\ 00$	0.00	0.00
26+80	$\varnothing_1 = \frac{\theta_i}{2} \rightarrow \frac{l_i}{20} D$ $= \frac{4.82}{20} \times 4^\circ\ 48' = 1^\circ\ 9.4'$	$2R \sin 1^\circ\ 9.4'$ $= 4.82$ m	$2R \sin 1^\circ\ 9.4'$ $= 4.82$ m
27+00	$\frac{\Theta i}{2} + D = 1^\circ\ 9.4' + 4^\circ\ 48'$ $= 5^\circ\ 57.4'$	$2R \sin 5^\circ\ 57.4'$ $= 24.78$	$2R \sin 4^\circ\ 48'$ $= 19.98$
27+20	$\frac{\Theta i}{2} + 2D = 1^\circ\ 9.4' + 2 \times 4^\circ\ 48' = 10^\circ\ 45.4'$	$2R \sin 10^\circ\ 45.4'$ $= 44.56$	$2R \sin 4^\circ\ 48'$ $= 19.98$
27+40	$\frac{\Theta i}{2} + 3D$ $= 15^\circ\ 33.4'$	$= 64.03$	$= 19.98$
27+60	$\frac{\Theta i}{2} + 4D = 20^\circ\ 21.4'$	$= 83.06$	$= 19.98$
P.T 27+69.57	$\varnothing_6 = \frac{\Theta i}{2} + 4D + \frac{\Theta f}{2} =$ $\varnothing_6 = \frac{\Theta i}{2} + 4D + \frac{l_f}{20} D$ $20^\circ\ 21.4' + \frac{9.57}{20} \times 4^\circ\ 48'$ $= 22^\circ\ 39.2'$ * $= \frac{\Delta^\circ}{2}$ Check *	$= 91.95$ m * Check * $C = 91.95$ m	$= 2R \sin 2^\circ\ 17.8'$ $= 9.57$

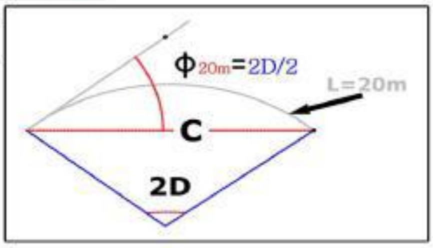
* Deflection Angle $= \Delta / 2 = 22^\circ\ 39'$ * Total Chord $= C = 91.95$ m

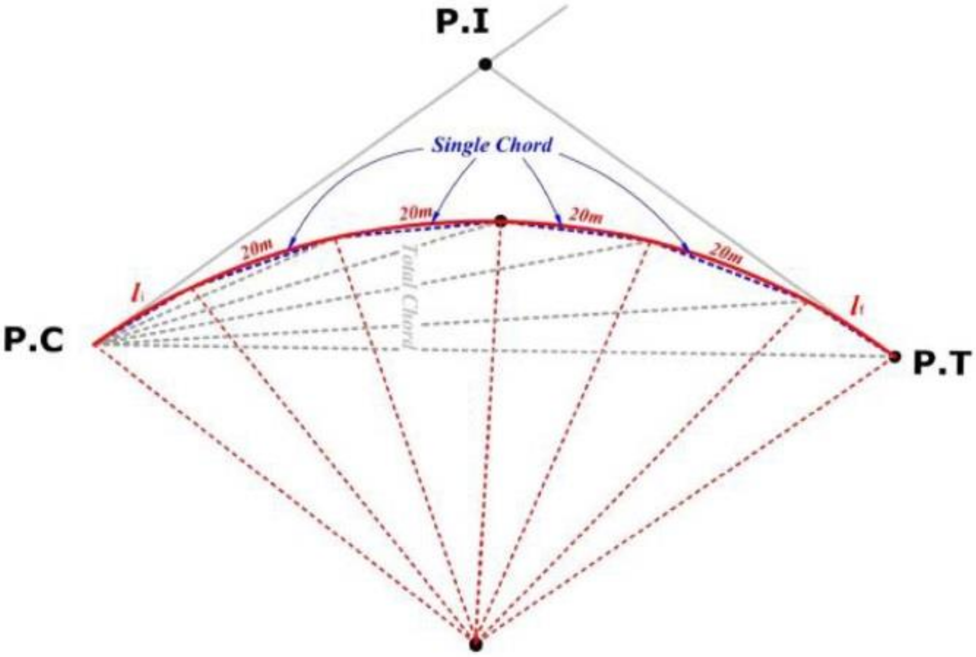
$\varnothing_i = \frac{l_i}{20} D$

$C = 2R \times \sin \varnothing_{20m}$

$\varnothing_{20m} = \frac{2D}{2}$

$\varnothing_f = \frac{l_f}{20} D$





The process of shedding by the method of total strings is done through zeroing on (P.I), then directing on each point through the angles, then measuring all the strings from point (P.C). . As for the method of single strings, it is done as before with regard to angles, but the strings are counted from point (P.C) to the first point, then from the first to the second, then from the second to the third... and so on.

Tangent offset method

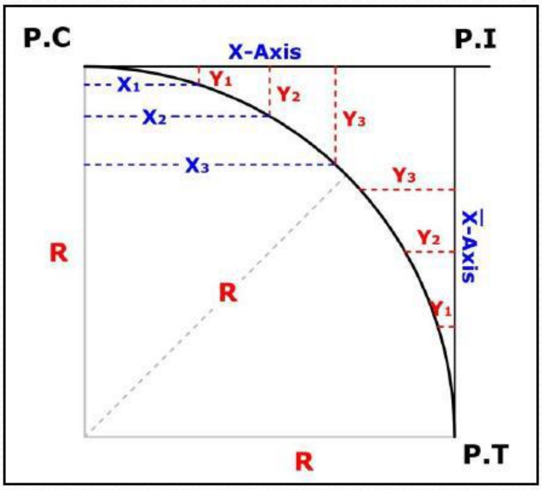
This method is called the coordinate method, as it depends on the basis of measuring horizontal and vertical distances from a point of origin. The columns are installed as follows:

- Determine the x-axis, and it is in the direction of (P.C) →(P.I), and it represents the x-axis distance from point P.C.
- The y-axis is identical to the radius, and the point (P.C) represents the first point of origin.
- The same process is applied from point (P.T), which represents the second point of origin.
- The y distance is measured perpendicular to the tangent and at every sigmoidal distance.

The y distances are calculated according to the following relationship:

$$y = R[1 - \sqrt{1 - \left(\frac{x}{R}\right)^2}$$

Point	x	$y = R\left[1 - \sqrt{1 - \left(\frac{x}{R}\right)^2}\right]$
(1)	$x_1 =$	$y_1 =$
(2)	$x_2 =$	$y_2 =$
(3)	$x_3 =$	$y_3 =$
(4)	$x_4 =$	$y_4 =$
⋮	⋮	⋮



On the other hand, this method is used most of the time if it is not possible to determine the center of the curve because of an obstruction.

1 .Determine the starting and ending points of the curve.

2 .We divide the tangent into a group of equal distances، and these distances represent the x-axis.

3 .We establish columns of division points on the x-axis.

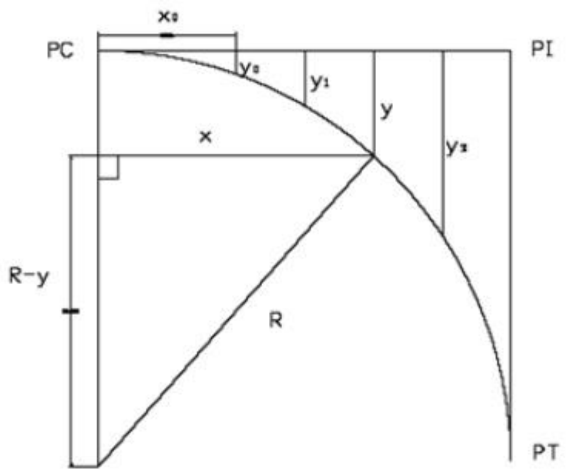
4 .We cut the columns built on the x-axis by the value of y calculated in the table shown below and from the law shown below as well, and prove it with arrows.

5 .To ensure accuracy in projecting the curve, we establish columns on the second tangent, thus the points are doubled and the curve is more accurate.

$$(R-y)^2 = R^2 - x^2$$

$$R - y = \sqrt{R^2 - x^2}$$

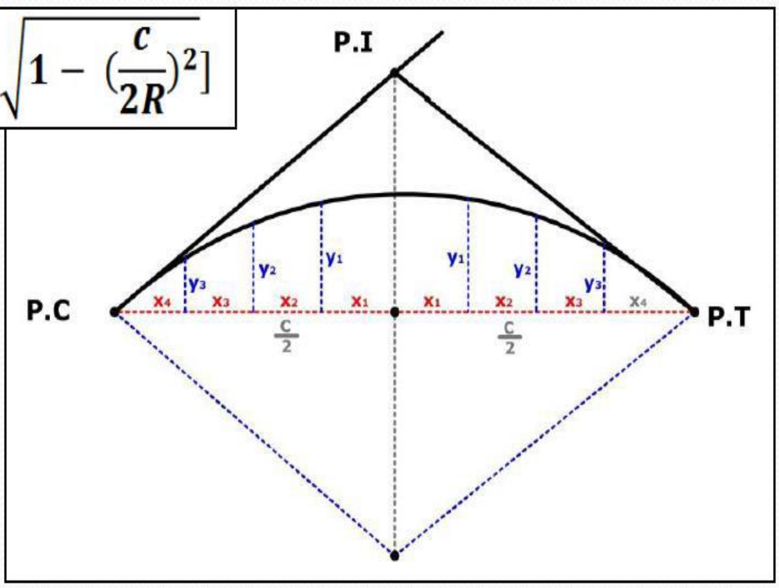
$$y = R - \sqrt{R^2 - x^2}$$



Chord offset method

1. In this method, the chord between (P.I & P.T) is first determined, and then it is divided into a number of equal parts.
2. Fixed default distances are fixed from the middle of the string towards the right and left (representing the x-coordinates).
3. The columns that represent the y-axis are calculated from the points established in the previous step and using the relationship the following mathematical, as shown in the figure.

$$y = R[\sqrt{1-(\frac{x}{R})^2} - \sqrt{1-(\frac{c}{2R})^2}]$$



Or

1. The chord is drawn between the starting and ending points of the curve (PC, PT) and determines its straightness by means of signs.
2. Divide half of the string into an appropriate number of parts, and with the same number we divide the other half of the string.
3. We prove the locations of the points by measuring the lengths of the segments from the midpoint of the hypotenuse (which represents the x-coordinate).
4. We measure the lengths of the columns built on those parts that represent the y-coordinates and calculated from the table shown below by the law shown below as well.
5. Columns shall be erected by tape and by the triangle method, or by one of the previously studied methods.

$$(K+y)^2 = R^2 - x^2$$

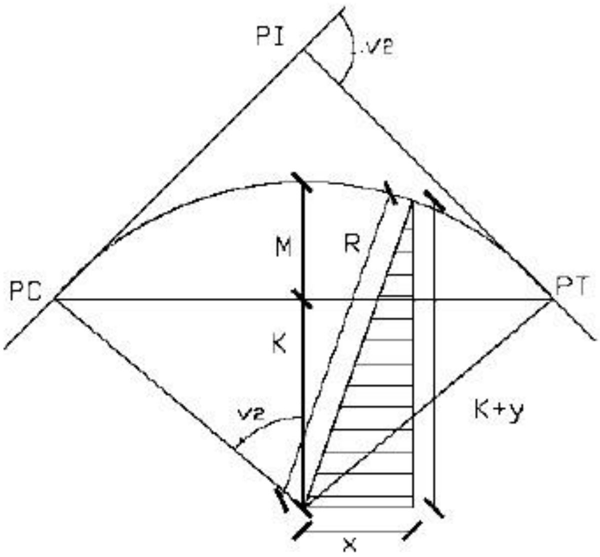
$$K + y = \sqrt{R^2 - x^2}$$

$$y = \sqrt{R^2 - x^2} - K$$

$$K = R - M$$

$$K = R^{*}\cos(\Delta/2)$$

$$K = \sqrt{R^2 - (C/2)^2}$$



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