

Surveying Engineering

Primary Classification of Survey

Plane Surveying	Geodetic Surveying
<ul style="list-style-type: none"> Mean surface of the earth is considered as plane. Used for small area < 195.5 km². Line joining two points is a line. It is less accurate. Used in engineering projects on large scale like, Bridge, dam. 	<ul style="list-style-type: none"> Actual surface of the earth is considered as curved surface. Use for large area > 195.5 km² It is an arc. It is more accurate. It is used to establishing control points for plane survey. All plumb lines arc radial

Types of scale

1. Plane Scale - There is possible to measure two dimensions, only such as unit and length or km and m.

2. Diagonal Scale - In this it is possible to show units, lengths, and hundredths or there are three successive dimensions can be measured at a time.

Note- Diagonal scale is based on principle of similarity of triangle.

3. Vernier Scale-

(a) Direct Vernier - Calibrated in same direction as of main scale.

- In this n division of vernier scale is equal to (n-1) divisions of main scale.

i.e $nV = (n-1)S$ in this $V < S$

(b) Retrograde Vernier- Vernier scale moves in opposite direction of main scale.

- For it $nV = (n+1)S$ for this $V > S$

(c) Extended vernier - $nV = (2n-1)S$

Least count $V = \frac{S}{n}$

4. Shrunk Scale -

= $\text{Original Scale} \times \text{shrinkage factor}$

and, $\text{Shrinkage factor} = \frac{\text{Shrunk length}}{\text{Actual length}}$

Note- Graphical scale does not affects due to shrinkage of map.

- Representative Fraction-**

$$R.F = \frac{\text{Map distance}}{\text{Ground distance}}$$

- Shrinkage ratio or S.F. =

$$S.F = \frac{\text{Shrunk length}}{\text{Original length}} = \frac{\text{Shrunk scale}}{\text{Original scale}}$$

- Correct distance on map

$$= \frac{\text{Measured distance on map}}{S.F.}$$

Correct area on map = $\frac{\text{Measured area on map}}{(S.F.)^2}$

Error due to use of wrong scale

Correct Length

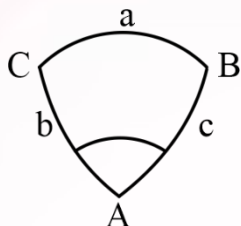
$$= \frac{\text{RF of wrong scale}}{\text{RF of correct scale}} \times \text{Measured Length}$$

Correct Area

$$= \left(\frac{\text{RF of wrong scale}}{\text{RF of correct scale}} \right)^2 \times \text{Measured Area}$$

Note-

- Minor control points are measured with higher degree of precision.
- Major control points are measured with lower degree of precision.

Properties of a spherical triangle


- Any angle,
 $[A \text{ or } B \text{ or } C < \pi \text{ or } 180^\circ]$
- Sum of three angle,
 $[\pi \text{ or } 180^\circ < (A+B+C) < 3\pi \text{ or } 540^\circ]$
- Sum of any two sides should be greater than third i.e.
 $[(a+b) > c, (b+c) > a, (a+c) > b]$

Least Count of Surveying Instrument

Instrument	Least Count
Vernier Theodolite	20"
Electronic Theodolite	1"
Prismatic compass	30'
Surveyor compass	15'
Levelling staff	5 mm or 0.005 m
Dumpy level	5 mm
Metric chain	20 cm
Theodolite-	
Main Scale	20'
Vernier Scale	20"
Total Station-	
Angle	1"
Distance	5 mm

Principal of different types of surveying work

Surveying Types	Principal
1. Surveying	i. To work from whole to part. ii. To locate a new station by at least two

	measurements (Linear or angular) from fixed reference point.
2. Chain Survey	Triangulation
3. Compass Survey	Traversing
4. Plane table Survey	Parallelism
5. Optical square	Double reflection

Types of Surveying

Topographical Surveys	It is used to determine the natural features of a country like, lakes, hills, roads, canal etc.
Cadastral Survey	Made to fixing of property line, calculation of area, etc.
City Survey	It is used to construction or layout for water supply system, sewer and other work.
Marine or hydrographic survey	It is deals with large water bodies such as navigation, harbour works etc.
Astronomical Survey	It is consists of observation of the heavenly bodies such as Sun or any Star.

Types of instrument used in survey and its application

Instrument	Application
Chain and compass	Linear and angular measurements
Chain and level	Linear measurements
Plane table	Plot plans of field observation for small scale in plane surface
Tacheometry	To measure horizontal and vertical angle in hilly regions

Basic measurements in surveying

Horizontal Distance	By chain. Tape, Tachcometer, Total station
Vertical Distance	Level, Total station, Tacheometer, Sextant, Abney level

Horizontal Angle	Theodolite, Compass, Clinometer, Total station
Vertical Angle	Theodolite, Sextant, Total station

Types of Chain and its length

Types of Chain	Length	No. of Links
Engineers Chain	100 ft	100
Gunter's chain/surveyor chain	66 ft	100
Revenue chain (use in cadastral survey)	33 ft	16
Metric Chain	30 m, 20 m	150, 100

- Length of each links - 20 cm
- Brass ring provided - every meter except tallies place

Length of chain	Brass ring	Tallies or tag
5m & 10m	-	At every meter
20 m & 30 m	Per m length	Every 5 m

Note-

Chain surveying is recommended when the area to be surveyed small in extent and on less undulating.

Maximum tolerance for chain

Per length	± 2 mm
10 m	± 3 mm
20 m	± 5 mm
30 m	± 8 mm

Important survey lines

Base line	Longest survey line passing through the centre of area.
Cheek line/proof line	Used to check the accuracy of the survey work.

Tie line/subsidiary line/ auxiliary line	To collect the details of nearby objects in an area. Tie lines to avoid long offsets from chain lines.
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Chain Survey instrument property

Instrument	Dimension
Arrows	Dia = 4 mm ,Length = 400 ± 5 mm Top ring dia = 50 mm
Pegs	Area = 2.5×2.5 cm ² to 3 cm \times 3 cm length = 15 cm
Ranging rod	Length = 2-3 m, Strip length = 20 cm each
Ranging pole	Length = 4-8 m

Angle measuring instrument

1. Cross staff	Used to setting out a right angle on chain line.
i. Open cross staff	Set out for 90° only
ii. French cross staff	for 45° and 90° & 135° (no. of line of sight = 2)
iii. Adjustable cross staff	for any angle 0° - 360°
2. Optical Square	Only for 90°
3. Prism Square	Only for 90°
4. Site Square	Only for 90°

Note- Angle b/w horizontal glass and index glass = 45°

Offset- Lateral measurement from chain line it is two types.

- Perpendicular offset
- Oblique offset

Note-

- Long offset > 15 m
- Short offset < 15 m
- Horizontal glass - Half silvered
- Index glass - Full silvered

Ranging

To locating intermediate point on survey line b/w two fixed end point.

(a) Direct Ranging -

- Minimum ranging rod required- 3
- Possible when stations are intervisible.

- It is done by Eye or Line Ranger
- (b) **Indirect/reciprocal ranging-**
- Minimum ranging rod required- 4
- It is done if stations are invisible due to elevated area or long sight distance

Obstacle in chaining

- Obstacle to ranging, **Ex.-Hill**
- Obstacle to chaining, **Ex.-River**
- Obstacle to both chaining and ranging, **Ex.-Building**

Note-

$$\boxed{\text{Error} = \text{Measured length} - \text{True length}}$$

Error in chain survey-

- Instrumental error
- Natural error
- Personal error

Types of error in linear measurement-

1. Cumulative/systematic error

- Occurs in same direction and tends to accumulate.
- Cumulative error \propto length of line (l)

2. Compensative/Accidental error-

- Not occurred in same direction.
- Compensative error $\propto \sqrt{l}$.

Types of error occurred during surveying

Cases	Errors
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Incorrect length of tape	Cumulative +ve or -ve
Bad ranging, clogging of chain ring with mud.	Cumulative +ve
Tape not stretched horizontally	Cumulative +ve
Tape not stretched tight and straight, but both ends in line	Cumulative +ve
Error due to temperature	Cumulative +ve or -ve
Variation in pull	Compensating +ve or -ve
Error due to sag	Cumulative +ve
Error in marking tape lengths	Compensating +ve or -ve
Disturbing arrows after they are set	Blunder
Errors in reading the tape	Mistake
Incorrect counting of tape length	Blunder
Careless holding and marking	Compensating +ve or -ve

Tape Correction

S.N.	Correction	Condition	Error	Correction	Formula
1.	Length	(a) Increases (b) Decreases	-Ve +Ve	+Ve -Ve	$L = l' \left(\frac{L'}{l} \right)$
2.	Temperature	(a) Increases (b) Decreases	-Ve +Ve	+Ve -Ve	$C_t = \alpha(T_m - T_0)L$
3.	Pull/Tension	(a) Increases (b) Decreases	-Ve +Ve	+Ve -Ve	$C_p = \frac{(P_m - P_0)}{AE} \times L$
4.	Sag	-	Always +Ve	Always -Ve	$C_s = \frac{W^2 l^3}{24P_m^2}$ or $\frac{w^2 l}{24n^2 P_m^2}$
5.	Slope	-	Always +Ve	Always -Ve	$C_{SL} = h^2/2L$ or $C_v = 2L \sin^2 \theta/2$

6.	Bad Ranging	-	Always +Ve	Always -Ve	$C_h = d^2/2L$
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- Error due to Incorrect chaining-

$$\text{Correct length} = \text{Measured length} \times \frac{\text{Incorrect chain length}}{\text{standard chain length}}$$

- In chain surveying field work limited to linear measurement only.

Note-

- Size of field book - 20 cm x 12 cm
- Correction per chain length for 100 links at a slope of $\alpha = \frac{1.5\alpha}{100}$
- Correction applied for each chain length along θ° slope. = $l(1 - \cos \theta)$
- Hypotenuse allowance = $l(1 - \cos \theta)$

Deferece Between Prismatic Compass and Surveyor Compass

Prismatic Compass	Surveyor compass
Magnetic needle is a broad needle	It is edge bar type
Graduated ring is attached with the needle do not rotate with the box	Attached with the box and rotate along with the box
Readings are taken with the help of the prism	Taken directly by seeing through top of the box
Sighting and reading are taken simultaneously	Can't be done simultaneously
Whole circle bearing (W.C.B.) are calculate	Quadranta) bearing (Q.B.) system is calculated.
Bearing of line measured with magnetic north in clockwise direction.	Bearing of a line measured eastward or westward from north or south whichever is nearer

Important definition

Azimuth/True bearing - Bearing of a line in reference to the horizontal true north (meridian).

Magnetic bearing - Horizontal angle b/w the magnetic meridian and a line.

Arbitrary bearing - Horizontal angle b/w the arbitrary meridian of a line.

Conversion of Q.B (Reduced bearing) to W.C.B.-

Q.B.	Quadrant	W.C.B.	Angle
N0E	I st	W.C.B. = Q.B	$0^\circ - 90^\circ$
S0E	II nd	$180^\circ - \text{Q.B.}$	$90^\circ - 180^\circ$
S0W	III rd	$180^\circ + \text{Q.B.}$	$180^\circ - 270^\circ$
N0W	IV th	$360^\circ - \text{Q.B.}$	$270^\circ - 360^\circ$

Conversion of W.C.B. to Q.B.

W.C.B	Quadrant	Q.B.	R.B./Q.B. value
$0^\circ - 90^\circ$	I st	Q.B = W.C.B.	N0E
$90^\circ - 180^\circ$	II nd	$180^\circ - \text{W.C.B}$	S0E
$180^\circ - 270^\circ$	III rd	$\text{W.C.B.} - 180^\circ$	S0W
$270^\circ - 360^\circ$	IV th	$360^\circ - \text{W.C.B.}$	N0W

Bearing of a Une

Fore Bearing - Bearing of a line in the progress of survey.

Back bearing - Bearing of a line taken opposite direction of the survey.

Relation b/w F.B. and B.B.

$$\text{B.B.} = \text{F.B} + 180^\circ]$$

Use, If $\text{F.B.} < 180^\circ$ then +Ve, If $\text{F.B.} > 180^\circ$ then - Ve

Note-

- In R.B. System, angle value does not change but direction (N → S and E → W) changes.

Temporary adjustment of prismatic compass sequence

Centering → Levelling → Focusing of prism

Local Attraction- Disturbance the magnetic needle from its normal under the influence of magnetic substance.

If,

$$\begin{array}{l} \boxed{B.B - F.B = 180} \quad (\text{No local attraction}) \\ \boxed{B.B - F.B \neq 180} \quad (\text{Affected by local attraction}) \end{array}$$

● **Magnetic declination**

It is a horizontal angle b/w true meridian and magnetic meridian.

$$\boxed{M.D. = \text{Truc meridian} - M.M.}$$

● **Angle of dip-**

It is the inclination angle of needle to the horizontal plane.

- Angle of dip - 0° at equator
= 90° at Magnetic poles

Important term

Lines	The line joining
Isoclinic lines	Points of equal dip
Aclinic lines	Points of zero dip
Isogonic lines	Points of equal declination
Agonic lines	Points of zero declination

Variation of magnetic declination

Secular variation	Due to over a long period of time due to gradual shift in earth's magnetic field.
Annual variation	Due to revolution of earth around the sun. (Yearly)
Diurnal variation	Due to rotation of earth about its own axis. It's more at pole, in day A summer time.
Irregular variation	Due to magnetic disturbances in earth's magnetic field.

Closing errors

The actual distance by which the traverse fails to close in a traverse survey.

$$\text{i.e., } \sum L \neq 0, \sum D \neq 0$$

Closing Error in the traverse,

$$e = \sqrt{(\sum L)^2 + (\sum D)^2}$$

Balancing of Traverse

1. Bowditch/compass rule-

- Used where Angle and distance are measured with same precision.
- Used in closed traverse

Assumption-

- Error in linear measurement $\propto \sqrt{l}$
- Error in angular measurement $\propto \sqrt{\frac{1}{\sqrt{l}}}$

2. Transit method-

Used where angular measurement are more precise than linear measurement.

$$C_L = \sum L \times \frac{L}{L_r}, C_D = \sum D \times \frac{D}{D_r}$$

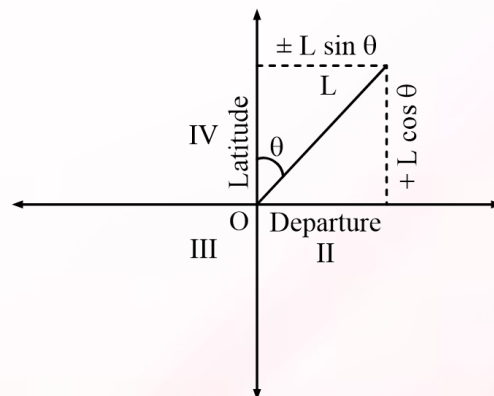
3. Axis Method-

Corrections are applied only to length and angles are measured very precisely.

Correction of any length

$$= \text{That length} \times \frac{\frac{1}{2} \text{Closing error}}{\text{Length of Axis}}$$

4. Graphical method- Use for rough survey work.



W.C.B.	Quadrant	Latitude	Departure	Remark
0°-90°	I	+	+	Latitude North +ve South -ve
90°-180°	II	-	+	
180°-270°	III	-	-	Departure East +ve West -ve
270°-360°	IV	+	-	

Check for close traverse by included angle

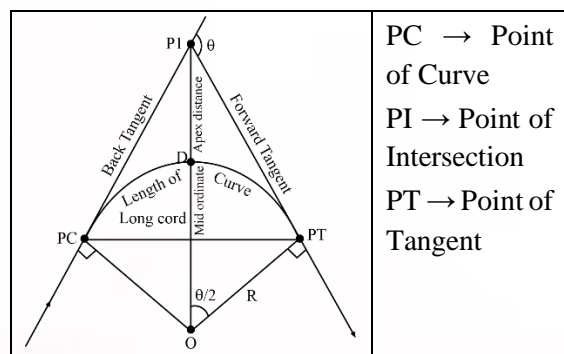
Sum of included angle = $(2N - 4) \times 90^\circ$

Sum of external angle = $(2N + 4) \times 90^\circ$

Degree of accuracy in traversing

Order of traversing	Accuracy
1 st	$6''\sqrt{N}$
2 nd	$15''\sqrt{N}$
3 rd	$30''\sqrt{N}$
Minor theodolite for detailing	$1'\sqrt{N}$
Compass traversing	$15'\sqrt{N}$

N = Number of angle measured



Element of Simple Circular Curve

Tangent length	$R \tan \theta/2$
Mid ordinate	$R(1 - \cos \theta/2) = 2R \sin^2 \theta/4$
Apex distance	$R(\sec \theta/2 - 1)$
Length of long chord	$2R \sin \theta/2$
Length of Curve	$rcR\theta$ 180°

Versine of curve -

It is perpendicular distance of the mid- point of a chord from the arc of a circle

Radius and versine relation in curve

$$V = \frac{C^2}{8R} \quad (C, V, R \text{ in m.})$$

$$V = \frac{125C^2}{R} \quad (V \text{ in cm } C \text{ and } R \text{ in m})$$

$$V = \frac{1.5C^2}{R} \quad (C \text{ \& } R \text{ in feet } V \text{ in inch})$$

Setting out of Curve

1. By ordinates from long chord-

$$O_x = \sqrt{(R^2 - x^2)} - (R - O_0)$$

2. By Successive bisection of arch-

$$\text{Offset} = R(1 - \cos \theta/2)$$

3. By offsets from tangent-

$$O_x = \frac{x^2}{2R}$$

4. By offsets from chord produced or deflection distance-

$$\frac{C_n}{2R} (C_{n-1} + C_n)$$

Relation between radius and degree of curve

Length of Arc	Relation
30 meter	$R = \frac{1720}{D^0} \text{ m}$
20 meter	$R = \frac{1146}{D^0} \text{ m}$
10 meter	$R = \frac{573}{D^0} \text{ m}$

100 feet	$R = \frac{5730}{D^0}$ feet
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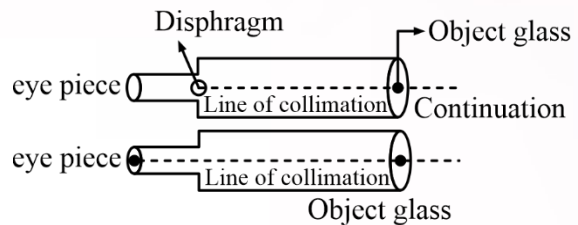
Leveling

Level line	Line laying on level surface normal to the plumb line or a line parallel to the mean spherical surface of the earth.
Horizontal line	It is tangential to the level line lying in the horizontal plane.
Level Surface	Parallel to the mean spheroidal surface of the earth.
Horizontal Surface	A surface tangential to the level surface at any point.
Datum	The Surface to which elevations are referred.
Bench mark	It is a fixed reference point of known elevation. It is establish by spirit leveling.
Reduced level	It is height of any point w.r.t. either M.S.L. on any bench mark of known R.L.
Resolving power	Power of a telescope to form distinguishable image of objects separated by small angular distance.
Alpanation combination	A compound lens free from spherical aberration.
Chromatic aberration	The defection which is blurred and coloured image formed.
Line of sight	A line joining intersection of the cross hairs to the optical centre of objective and its continuation.

Line of collimation	If line of sight is horizontal the it is called line of collimation.
Definition	The capability of a telescope to produce sharp image.

Note-

Mean sea level (MSL) adopted by survey of India for reference is located at Mumbai.



- **Axis of bubble tube-**

An imaginary line tangential to the longitudinal curve of the bubble tube at its middle point.

Permanent adjustment of level-

1. Axis of bubble tube should be perpendicular to the vertical axis of instrument.
2. Horizontal cross hair should lie in the plane perpendicular to the vertical axis.
3. Line of sight should be parallel to the axis of level/bubble tube. **Two peg test performed to insure its.**

Levelling staff
(i) Target staff (L.C. - 0.001 m)

Reading taken by staff man

(ii) Self Reading Staff-

Reading taken by directly Instrument man

Ex.-Solid staff, folding staff, Telescopic staff, invar precision staff.

Important Terms used in levelling

Vertical axis	Axis about which telescope can be rotate in horizontal plane.
Horizontal/Trunion axis	Axis about which telescope can be rotate in vertical plane.

Back Sight (B.S.)	It is the first reading taken after setting up the instrument.
Fore Sight (F.S.)	It is the last reading taken from on instrument station. It indicate shifting the shifting of instrument.
Intermediate sight (I.S.)	All reading excepts B.S. and F.S.
Change Point (C.P.)	The point where F.S. and B.S. both are taken.

Height of Instrument

- **Arithmetic check-**

- (i) **For rise and fall method-**

$$\sum B.S. - \sum F.S. = \sum Rise - \sum Fall = \text{Last R.L.} - \text{First R.L.}$$

Total check point = 3

- (ii) **For H.I method-**

$$\sum B.S. - \sum F.S. = \text{Last R.L.} - \text{First R.L.}$$

Total check point = 2

Rise and fall method	H.I. method
It is more tedious method.	It is rapid method
Check provided for B.S., F.S. and I.S.	Check provided only for B.S. and F.S.
Have less error	Have more error

Types of Correction	Correction to staff reading
Curvature Correction	$C_c = -\frac{d^2}{2R}$ or $-0.0785d^2$ D, in km, C_c in m
Refraction Correction	$C_R = \frac{1}{7} \times \frac{d^2}{2R} = +\frac{1}{7}C_c$ $= 0.01121 d^2m$

Combined correction	$C = -\frac{6}{7} \times \frac{d^2}{R}$ $= -0.06728 d^2m$
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Note- Distance of visible horizon,

$$d = 3.8553\sqrt{c} \text{ km } \quad c, \text{ height of object in m}$$

Various types of levelling-

Differential/Compound levelling	It is used when difference of elevation b/w two points is large (hill), obstacles b/w the points.
Check levelling	Its purpose is checking of elevations which have already taken.
Fly Levelling	It is useful for linear structure as roads, canal, railways etc. • Observation taken only B.S. and F.S.
Profile levelling	It is used to determine the elevations along the central line of the ground surface like road, canal etc.
Cross levelling	It is done to obtain the elevations perpendicular to aligned surface like road and canal.
Reciprocal levelling	This method is done when the instrument cannot be set up b/w the two points because of an obstruction like valley, river etc.

Note

- Error due to refraction is not completely eliminated in reciprocal levelling and it also does not eliminate parallax error.

Average level difference,

$$H = \frac{(h_a - h_b) + (h'_a - h'_b)}{2}$$

Sensitiveness of bubble tube

$$\alpha' = \frac{\ell}{r} = \frac{S}{nD} \times 206265 \text{ Second}$$

Factors affecting the sensitiveness of bubble-

Factors	Sensitivity of bubble
Length of bubble ↑	↑
Internal smoothness ↑	↑
Diameter of tube ↑	↑
Viscosity ↑	↓
Temperature ↑	↓
Radius of curvature ↑	↑

Note-

- Correct sequence of temporary adjustment of level-

Centering → Levelling → Focusing

- **Elimination of parallax-**

1. By focusing eye-piece
2. By focusing objective lens.

Contouring-

Contour Line	It is an imaginary line joining point of equal elevation on ground.
Contour Interval	Vertical distance b/w two contour lines.
Horizontal equivalent	Horizontal distance b/w two contour lines.

Some suitable values of contour interval

Scale of map	Types of ground	Contour interval in meter
Large, (1 cm = 10 m or less)	Flat	0.2 to 0.5
	rolling Hilly	0.5 to 1 1, 1.5 or 2
Intermediate (1 cm = 10 m to 100 m)	Flat	0.5, 1 or 1.5
	rolling Hilly	1, 1.5 or 2 2, 2.5 or 3
Small (1 cm = 100 m or More)	Flat	1,2 or 3
	rolling	2 to 5
	Hilly Mountainous	5 to 10 10,25 or 50

Characteristics of contour lines-

- Two contour lines are not meet at point nor cut each other.

Ex-Overhanging cliff, Vertical cliff or Wall

- Closed contour lines with higher value inside centre indicate hill or rising ground.
- Closed contour lines with lower value towards centre indicate depression, pond or lake.
- Contour lines cut the ridge or watershed line and valley or drainage line at right angles (90°)
- If in a loop elevation of contour lines increase towards inside it indicates ridge.
- And if this value decreases towards inside of loop, it indicate a valley line.
- V-shaped contours with convexity towards higher ground represent hills/valley.
- U-shaped contours with convexity towards lower ground represents ridge.

Methods of contouring and its suitability-

Methods	Suitability
1. Direct method	Regular ground surface for large scale maps and small area. It is very slow, tedious and costly.
2. Indirect method (Mostly used) (i) Method of cross section (ii) Method of square (iii) Tacheometric method	For road, canal, railway or alignment survey. For small open area where close vertical interval contours required For hilly areas.

Method of interpolation

- (i) Estimation method (**Simple and rapid method**)
- (ii) Arithmetic/computation method (**Best method**)
- (iii) Graphical method

Note-

$\text{Contour interval} = \frac{25}{\text{No. of cm per km}}$
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Plane table-

Size of plane table- 60 cm × 50 an, 75 cm × 60 cm, and 100 cm × 75 cm

Method of orientation

- (i) Trough compass/magnetic meridian method
- (ii) Back sighting method

Methods to solve three point problem

- (i) Mechanical/Tracing paper method
- (ii) Graphical/Bessel's method
- (iii) Lehman's/Trial and error method

Methods of Plane table survey

- (i) Radiation method (for small and open areas)
- (ii) Intersection method
- (iii) Traversing method
- (iv) Resection method

Telescopic Alidade

To measure directly horizontal and vertical distance.

Important terminology related to theodolite-

Transit Theodolite	Can be rotate (180°) about horizontal/trunnion axis in the vertical plane.
Swinging the theodolite	It is the process of turning the telescope in horizontal plane. Right swing- Telescope rotated in clockwise direction. Left Swing- Rotated Anticlockwise direction.
Face Right	Vertical circle of theodolite is on the right hand side of the surveyor.
Face left	vertical circle is in left hand side
Transiting	Operation of revolving the telescope by 180° about horizontal/trunnion axis in the vertical plane.

Fundamental relation between axis of theodolite and test

Axis relation	Test
Horizontal axis should be perpendicular to vertical axis.	Spire test
Vertical axis should be perpendicular to axis of level tube	Plate level test
Line of collimation should be perpendicular to horizontal	Azimuth test

Axis of bubble tube should be parallel to line of collimation	Vertical arc index test
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Temporary adjustments of a Theodolite-

- i. Setting over the station
- ii. Levelling up
- iii. Elimination of parallax

Parallax

It is an error occurred when image formed by objective lens is not in the same plane with cross hair of telescope.

Elimination of parallax-

- (i) By focusing of eye-piece
- (ii) By focusing of objective lens

Tacheometer

$$\text{Multiplying constant} = \frac{f}{i} = 100$$

$$\text{Additive constant} = f + i = 0$$

Tacheometer Survey methods-

- (i) Fixed hair or stadia method
- (ii) Movable hair or substance tachcometer method
- (iii) Tangential method.

Stadia Method
1. Distance and elevation for staff vertical inclined sight-

Horizontal distance,

$$D = k.s \frac{\sin 2\theta}{2} + c \sin \theta$$

$$\text{Vertical intercept, } V = k.s \frac{\sin 2\theta}{2} + c \sin \theta$$

2. Distance of Elevation formulae for staff normal.

Horizontal distance,

$$D = (k.s + c) \cos \theta \pm r \sin \theta$$

Vertical intercept, $V = (k.s + c) \sin \theta$

$$\left(\begin{array}{l} +, \text{Elevation Angle} \\ -, \text{Depression Angle} \end{array} \right)$$

3. Elevation formulae for horizontal sight Distance -

$$D = k.s + c$$

Subtense bar/horizontal stave-

It can measure horizontal and vertical distance in places where chaining is impossible because of undulations and rough topography.

- It can measure short distance upto 200 m.
- Length - 2 – 3 m

Minor Survey instrument and their use-

Instrument	Use
Abney level (use as clinometer)	Measurement of slope, vertical angle, tracing grade contour, setting of grade
Clinometer	Angle
Hand level	Locating a contour, preliminary survey
Pantagraph	Enlarge or reduce the map
Planimeter	To measure undulated area
Sextant	To measure horizontal and vertical angle