

Chapter-1

TACHEOMETRY

- 1.1. Principles, stadia constants determination
- 1.2. Stadia tacheometry with staff held vertical and with line of collimation horizontal or inclined, numerical problems
- 1.3. Elevations and distances of staff stations - numerical problems

INTRODUCTION

Tacheometry is a branch of surveying in which horizontal and vertical distances are determined by taking angular observations with an instrument known as a tacheometer.

- chaining operation is completely eliminated.
- Adopted in rough and difficult terrain.
- Also used in location survey for railways, Roads, reservoirs etc.
- Though not very accurate, it is very rapid.

INSTRUMENTS USED

(a) The Tacheometer: Transit theodolite fitted with a stadia diaphragm and an anallatic lens.



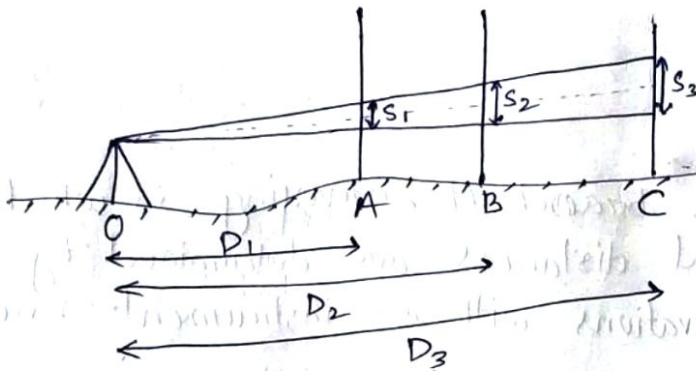
Fig: stadia diaphragm;

(b) The levelling staff: for short distance, 4m long can be folded into 3 parts.

Stadia Rod: for long sights, 4m long, may be folded or telescopic with gradications comparatively bold and clear.

1.1. Principle :

The principle of tacheometry is based on the property of isosceles triangles, where the ratio of the distance of the base from the apex and the length of the base is always constant.



So

according to the stated principle

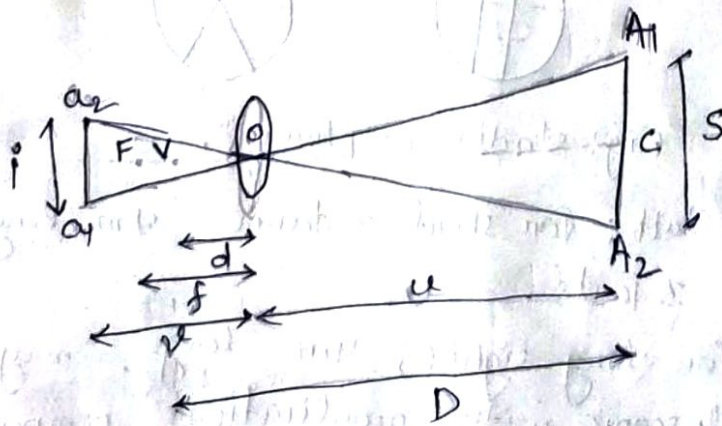
$$\frac{D_1}{s_1} = \frac{D_2}{s_2} = \frac{D_3}{s_3} = \frac{f}{i} \text{ (constant)}$$

Here $\frac{f}{i}$ = multiplying constant.

f = focal length of objective

i = stadia intercept.

THEORY OF STADIA TACHEOMETRY



Notations

O - optical centre

i = length of image

s = staff intercept.

F = focus

V = vertical axis of instrument.

f = focal length

d = distance b/w 'O' and 'V'

u = distance between 'O' and staff.

v = distance b/w 'O' and image.

from similar Δ $a_1 O a_2$ and $A_1 O A_2$

$$\frac{i}{s} = \frac{v}{u} \Rightarrow \boxed{v = \frac{i u}{s}} \quad \text{--- (1)}$$

from properties of lenses

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f} \quad \text{--- (2)}$$

substituting value of v

$$\begin{aligned} \frac{1}{u} + \frac{1}{\frac{i u}{s}} &= \frac{1}{f} \\ \Rightarrow \frac{1}{u} \left(1 + \frac{s}{i}\right) &= \frac{1}{f} \\ \Rightarrow u &= \left(\frac{s}{i} + 1\right) f \end{aligned}$$

But $D = u + d$

$$\begin{aligned} \text{So } D &= \left(\frac{s}{i} + 1\right) f + d \\ &= \frac{s}{i} f + f + d \end{aligned}$$

$$D = \left(\frac{f}{i}\right) s + (f + d) \quad \text{--- (3)}$$

Here $\left(\frac{f}{i}\right)$ & $(f + d)$ are known as tacheometry constants

$(f + d)$ = additive constant.

→ By adopting an anallactic lens in the telescope of a tacheometer $\frac{f}{i}$ is made 100 & the additive constant zero.

DETERMINATION OF STADIA CONSTANT

The constants may be determined by

1. Laboratory measurement:

→ The focal length f can be determined by means of an optical bench, according to the equation

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

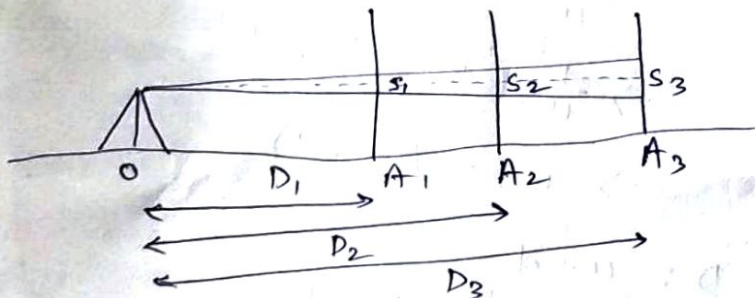
→ The stadia intercept i can be measured from the diaphragm with the help of a vernier calliper

→ The distance d can also be measured.

Hence, the multiplying constant $\frac{f}{i}$ and additive constant $f+d$ can be calculated.

2. FIELD MEASUREMENT:

→ A fairly level ground is selected. The tachometer is set up at O and pegs are fixed at A_1 , A_2 and A_3 known distance apart.



→ The stadia intercepts are noted at each of the pegs as s_1 , s_2 and s_3 respectively.

→ The horizontal distances of the pegs from ' O ' are accurately measured, let it be D_1 , D_2 & D_3 respectively.

→ Substitute these values in general equation

$$D = \left(\frac{f}{i}\right) S + (f+d)$$

we get a number of equations

→ By solving the equations in pairs, several values of f_i and $f+d$ are obtained. Take the mean as required constant.

Example: Determine the values of stadia constants from the following observations.

Instrument Station	Stabb reading on	Distance (m)	Stadia Readings	
			Upper	Lower
O	A	150	1.255	2.750
	B	200	1.000	3.000
	C	250	0.750	3.255

1.2 STADIA TACHEOMETRY:

Tacheometry involves mainly two methods

- The stadia method
- The tangential method

THE STADIA METHOD

In this method the diaphragm of the tacheometer is provided with two stadia hairs (upper & lower).

- Looking through ^{the telescope} the stadia hair readings are taken.
- The difference in these readings gives the staff intercept.
- The distance b/w station & staff is determined by multiplying staff intercept and stadia constant.
- It is of two types

● FIXED HAIR METHOD

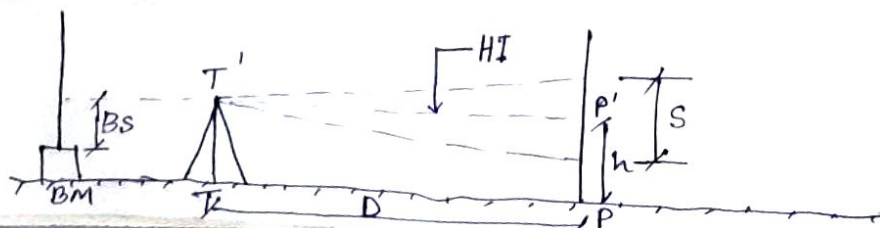
- The distance b/w the stadia hairs is fixed.
- The value of the staff intercept varies with the distance
- The distance b/w station and the staff can be obtained by multiplying the staff intercept by the stadia constant.

● MOVABLE HAIR METHOD

- The stadia hairs are not fixed, can be moved or adjusted by micrometer screws.
- Staff is provided with two known targets. with help of micrometer screws
- The distance b/w stadia hairs is so adjusted that upper hair bisects upper target & lower hair bisects lower target.
- The variable stadia intercept is measured and the required distance is then computed.
- Generally Not used.

FIXED HAIR METHOD

Case-1: When line of sight is horizontal and staff is held vertical



We know that

$$D = \left(\frac{f}{i}\right) S + (f+d)$$

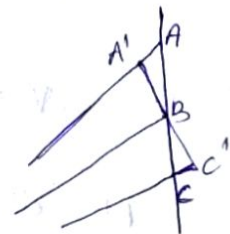
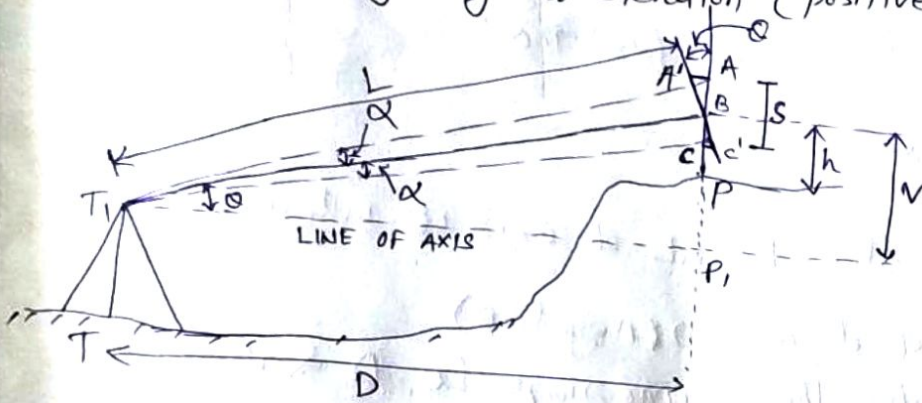
Where $\frac{f}{i} = 100$ & $(f+d) = 0$ for tachometer fitted with anallatic lens

$$RL \text{ of stabb station } - P = HI - h$$

$$HI = RL \text{ of BM} + BS$$

Case-II: When line of sight is inclined, but stabb is held vertical.

(a) Considering Angle of Elevation (positive)



$A'C'$ is drawn perpendicular to the central ray T_1B .

$$\text{Now } L = \left(\frac{f}{i}\right) A'C' + (f+d)$$

$$D = L \cos \theta$$

$$= \left(\frac{f}{i}\right) A'C' \cos \theta + (f+d) \cos \theta \quad \text{--- (1)}$$

Now $A'C'$ is to be expressed in terms of AC (i.e. S) in $\Delta ABA'$ and CBC'

$$\angle ABA' = \angle CBC' = \theta$$

$$\angle AA'B = 90^\circ + \alpha$$

$$\angle BC'C = 90^\circ - \alpha$$

The angle α is very small

$$\text{so, } \angle AA'B = \angle BC'C = 90^\circ$$

$$\Rightarrow AC' = AC \cos \theta = S \cos \theta$$

from Eq. ①

$$D = \frac{f}{i} (S \cos \theta) \cos \theta + (f+d) \cos \theta$$

$$= \frac{f}{i} S \cos^2 \theta + (f+d) \cos \theta$$

Also,

$$V = L \sin \theta$$

$$= \left[\frac{f}{i} S \cos \theta + (f+d) \right] \sin \theta$$

$$= \frac{f}{i} S \cos \theta \sin \theta + (f+d) \sin \theta$$

$$\Rightarrow V = \left(\frac{f}{i} \right) S \frac{\sin 2\theta}{2} + (f+d) \sin \theta$$

And $V = D \tan \theta$

Now RL of staff station $P = RL$ of axis of instrument $+V - h$

(b) Considering angle of depression (negative)

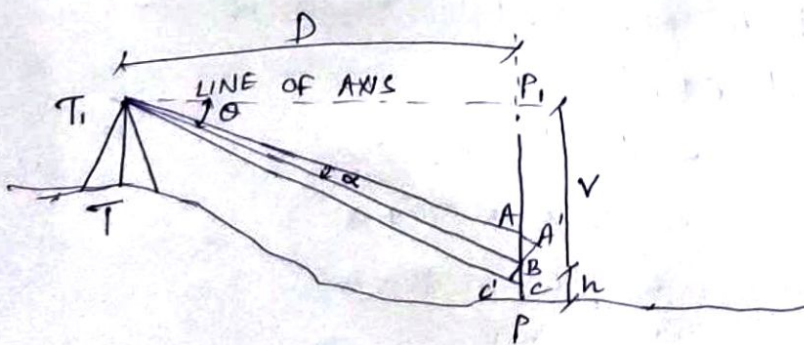
In this method also the expressions for D & V are same as in (a).

i.e

$$D = \frac{f}{i} \times S \cos^2 \theta + (f+d) \cos \theta$$

$$V = \frac{f}{i} \times \frac{S \sin 2\theta}{2} + (f+d) \sin \theta$$

RL of staff station, $P = RL$ of axis of instrument $- V - h$



MOVEABLE HAIR METHOD

When the line of sight is horizontal

$$D = \frac{C \times S}{n} + (f+d)$$

where

C = constant varying from 600 to 1000

n = sum of the readings in the micrometer

S = staff intercept (known)

When the line of sight is inclined

$$D = \frac{C S \cos^2 \theta}{n} + (f+d) \cos \theta$$

1.3 Numerical Problems

EX1: A tachometer was set up at a station C and the following readings were obtained on a staff vertically held.

Inst. station	Staff station	Vertical angle	Hair readings (m)	Remark
C	BM	$-5^\circ 20'$	1.50, 1.800, 2.450	RL of BM = 750.5 m
C	D	$8^\circ 12'$	0.750, 1.500, 2.250	

Calculate the horizontal distance CD and RL of D, when the constants of instrument are 100 and 0.15.

$$V_1 = 12.045 \text{ m}$$

$$V_2 = 21.197 \text{ m}$$

$$D_2 = 147.097 \text{ m}$$

$$\text{RL of D} = 784.042 \text{ m}$$

EX2: The following observations were taken with a tachometer fitted with an anallatic lens, the staff being held vertically. The constant of the tachometer is 100.

Inst. station	HI	Staff station	Vertical angle	Staff Readings (m)	Remark
P	1.255	BM	$-4^\circ 20'$	1.325, 1.825, 2.325	RL of BM = 255.750 m
P	1.255	A	$+6^\circ 30'$	0.850, 1.600, 2.350	
B	1.450	A	$-7^\circ 24'$	1.715, 2.315, 2.915	

Calculate the RL of B and the distance b/w A and B.

(Ans - $V_1 = 7.534 \text{ m}$, $V_2 = 16.871 \text{ m}$, $V_3 = 15.326 \text{ m}$, RL of A = 280.380 m, RL of B = 296.571 m, AB = 118.009 m)

CURVES

- 2.1 Compound, Reverse and transition curves, Purpose and uses of different types of curves in field.
- 2.2. Elements of circular curves, Numerical problems
- 2.3. Preparation of curve table for setting out.
- 2.4. Setting out of circular curve by chain and tape and by instrument angular methods (i) offsets from long chord (ii) successive bisection of arc (iii) offsets from tangents (iv) offsets from chord produced (v) Rankine's method tangent angles (No derivation)
- 2.5 obstacles in curve ranging - point of intersection inaccessible.

2.1 CURVES

Curves are regular bends provided in the lines of communication like roads, Railway and canals etc. to bring about gradual change of direction or gradient.

→ It may be of two types

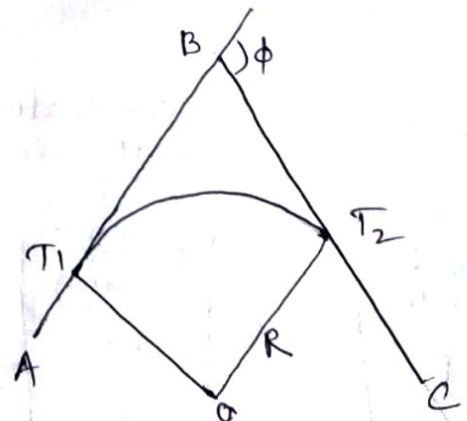
- ① Horizontal curves
- ② Vertical curves

HORIZONTAL CURVES

The following are the different types of horizontal curves

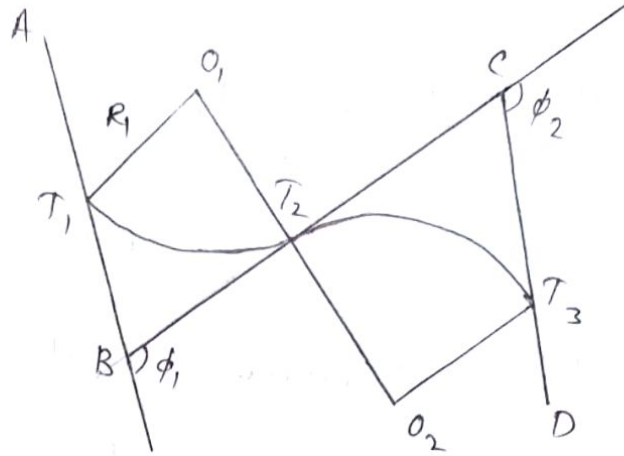
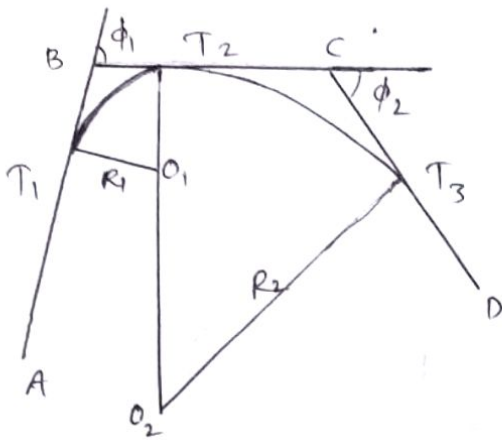
1. Simple circular curve:

When a curve consists of a single arc with a constant radius connecting the two tangents, it is said to be a circular curve.



2. Compound curve

When a curve consists of two or more arcs with different radii, it is called a compound curve. Such a curve lies on the same side of a common tangent and the centres of the different arcs lie on the same side of their respective tangents.

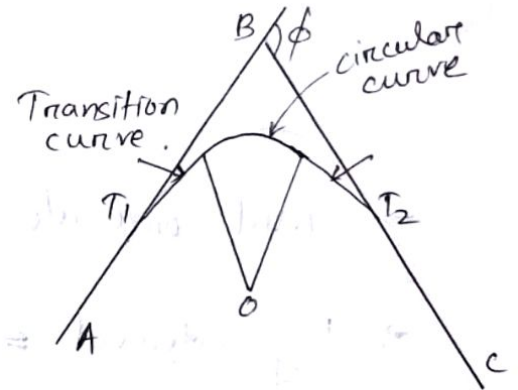


3. Reverse curve

A reverse curve consists of two arcs bending in opposite directions. Their centres lie on opposite sides of the curve. Their radii may be either equal or different and they have one common tangent.

4. Transition curve:

A curve of variable radius is known as a transition curve. It is also called a spiral curve or easement curve. In railways, such a curve is provided on both sides of a circular curve to minimize superelevation. Excessive superelevation may cause wear and tear of the rail section and discomfort to passenger.



2.2. Elements of circular curve

→ Angle of intersection is given

$$\phi = 180^\circ - I$$

(I = Angle of intersection)

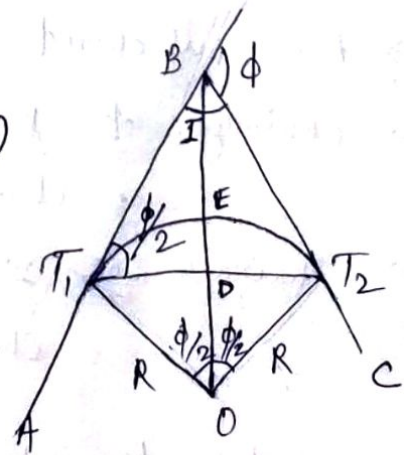
→ Radius is not given

$$R = \frac{1719}{D}$$

(D = Degree of curve)

→ Tangent length BT_1 or BT_2

$$BT_1 \text{ or } BT_2 = R \tan \frac{\phi}{2}$$



$$\begin{aligned} \rightarrow \text{Length of curve} &= T_1 E T_2 \\ &= R \times \phi \text{ radians} \\ &= \frac{\pi}{180^\circ} R \phi^\circ \end{aligned}$$

$$\rightarrow \text{Length of curve} = \frac{30 \phi}{D} \quad (\text{if } D \text{ is given})$$

$$\rightarrow \text{Length of long chord} = \boxed{\begin{aligned} 2 T_1 D &= 20 T_1 \sin \phi/2 \\ &= 2 R \sin \phi/2 \end{aligned}}$$

$$\begin{aligned} \rightarrow \text{Apex distance} &= BE = OB - OE \\ &= R \sec \phi/2 - R \\ &= R (\sec \phi/2 - 1) \end{aligned}$$

$$\begin{aligned} \rightarrow \text{mid ordinate} &= DE = OE - OD \\ &= R - R \cos \phi/2 = R (1 - \cos \phi/2) \end{aligned}$$

$$\rightarrow \text{Peg interval} \leq \frac{R}{20}$$

Railway (20-30 m)
Road (< 10 m)

→ Initial subchord

→ final subchord

→ chainage of 1st tangent point
= chainage of B - tangent length.

→ chainage of 2nd tangent point
= chainage of 1st tangent point + curve length

Q Two tangents intersect at a chainage of 1320.5 m, the deflection being 24° . Calculate the following quantities for setting out a curve of radius 275 m.

- ①
- (a) Tangent length
 - (b) Length of long chord
 - (c) Length of the curve
 - (d) Apex distance
 - (e) versed sine of curve / Mid ordinate
 - (f) Chainage of point of commencement and tangency.

24. ~~Setting out of~~ ~~circular curve~~

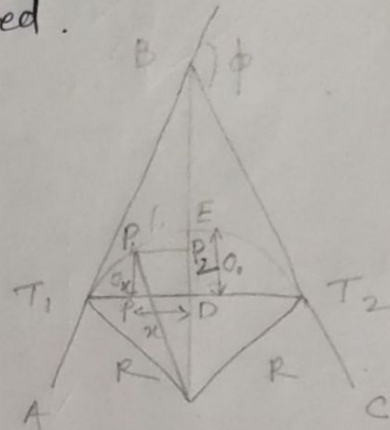
2.4. Setting out of circular curve by chain and tape.

→ It can be done by employing the following general methods.

- Taking offsets from long chord
- Successive bisection of arc
- Taking offsets from the tangents
- Taking offsets from chord produced.

Offsets or ordinates from long chord

Let AB and BC be two tangents meeting at a point B, with a deflection angle ϕ .



→ For setting out the curve following data are calculated.

→ Tangent length $TL = R \tan \phi/2$

→ Tangent points T_1 and T_2 are marked.

→ Length of curve $CL = \frac{\pi}{180} R \phi$

→ The chainages of T_1 and T_2 are found out.

→ Length of long chord $L = 2R \sin \phi/2$

→ Long chord is divided into two halves.

→ Mid ordinate $O_0 = DE = R(1 - \cos \phi/2)$

and $OD = R - O_0$

From ΔOT_1D $OT_1^2 = OD^2 + T_1D^2$

$$R^2 = (R - O_0)^2 + \left(\frac{L}{2}\right)^2$$

$$R - O_0 = \sqrt{R^2 - \left(\frac{L}{2}\right)^2}$$

$$O_0 = R - \sqrt{R^2 - \left(\frac{L}{2}\right)^2}$$

→ Let P be a point at a distance x from D. Then PP_1 (O_x) is required ordinate. A line P_1P_2 is drawn parallel to T_1, T_2 . From triang OP_1P_2 ,

$$OP_1^2 = OP_2^2 + P_1P_2^2$$

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

$$\Rightarrow R - O_0 + O_x = \sqrt{R^2 - x^2}$$

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

→ The ordinates for the right half are similar to these ordinates for the left half.

Q Two tangents AB and BC intersect at a point B at chainage 150.5 m. Calculate all the necessary data for setting out a circular curve of radius 100 m and deflection angle 30° by the method of offsets from the long chord.

Successive Bisection of Arcs.

→ AB & BC are two tangents intersecting at B with deflection angle ϕ .

→ Tangent length is calculated and T_1 & T_2 are marked.

→ T_1T_2 is length of long chord A is bisected at D.

→ A perpendicular is set out and point D_1 is cut so that

$$DD_1 = R(1 - \cos \phi/2) = \text{mid ordinate}$$

→ Again distance T_1D_1 & T_2D_2 is measured and bisected at C and E.

$$\text{Now } CC_1 \text{ \& } EE_1 = R(1 - \cos \phi/4) = \text{New mid ordinate}$$

→ The perpendiculars are drawn at C & E and point C_1 & E_1 are cut.

→ This process is continued until the bisection is not practically possible.

Offsets from tangent method

This may be

→ Radial

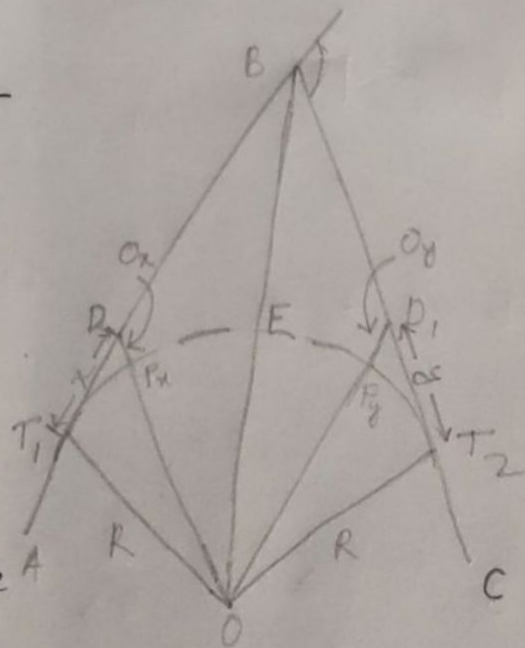
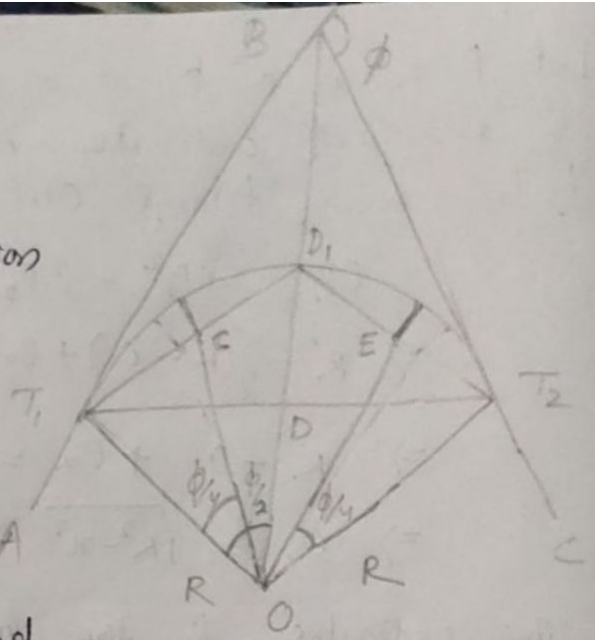
→ Perpendicular

Radial Offset

→ AB and BC are two tangents intersecting at B and tangent points are T_1 and T_2 .

→ Let us take a point D on the rear tangent AB such that

$$T_1D = x$$



Let O_x be the radial offset at D.

from $\triangle T_1 O D$ $OT_1^2 + T_1 D^2 = OD^2$

$$\Rightarrow R^2 + x^2 = (R + O_x)^2$$

$$\Rightarrow O_x = \sqrt{R^2 + x^2} - R$$

→ Distance O_x is cut off from the radial line OD to get first point of curve P_x .

→ By increasing value of x we will get number of O_x and

→ from T_1 , one half of the curve can be set out.

→ following similar procedure ^{from T_2} we can obtain points of curve P_y for the other half of curve.

By Perpendicular offsets:

→ AB and BC are two tangents intersecting at B, and the tangent points are T_1 and T_2

→ A point D is taken along AB at a distance x from T_1 .

Let O_x be the perpendicular offset at D. The line EP_x is parallel to $T_1 D$

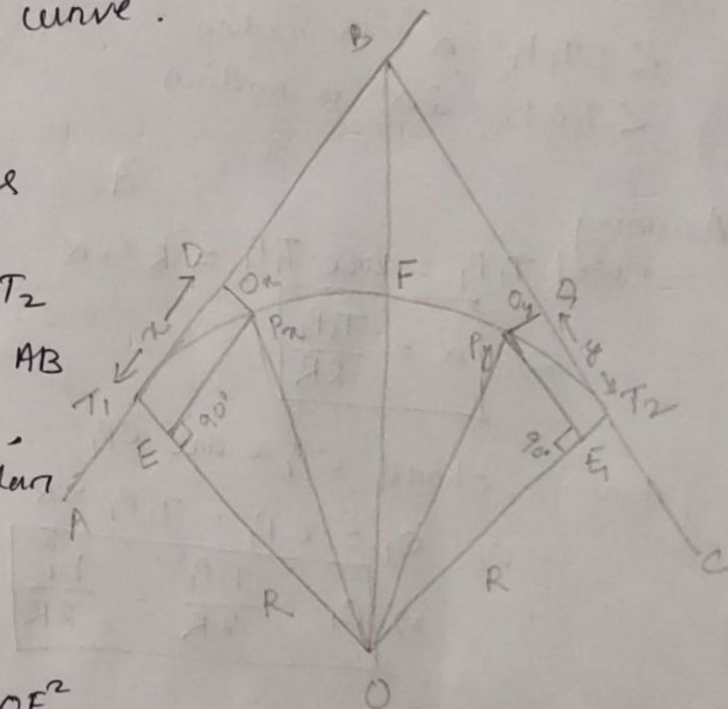
From $\triangle OEP_x$,

$$OP_x^2 = EP_x^2 + OE^2$$

$$\Rightarrow R^2 = x^2 + (R - O_x)^2$$

$$\Rightarrow R - O_x = \sqrt{R^2 - x^2}$$

$$\Rightarrow O_x = R - \sqrt{R^2 - x^2}$$



→ The distance O_x is drawn perpendicular at D to get P_x

→ Similarly by increasing x a series of offsets are obtained drawing which we will get point of curve for one half

→ for other half a distance y is taken from T_2 to mark D_1 .

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

- Distance Oy is drawn perpendicular at D_1 to get point P_y .
 → This process is continued by increasing y until we reach the apex F .

Offsets from chord Produced:

Let,

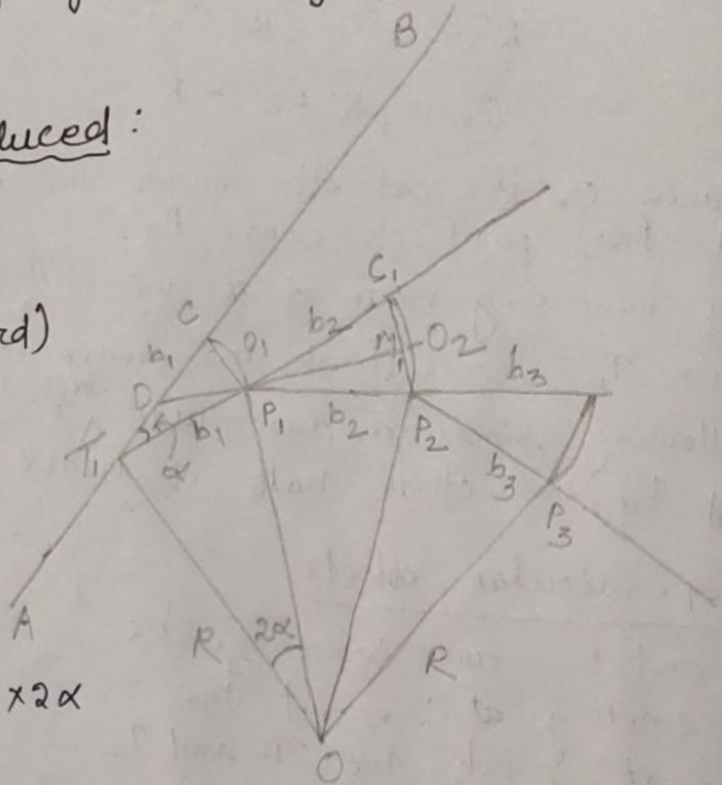
AB = Rear tangent point.

$T_1C = T_1P_1 = b_1$
 (first cord/initial sub chord)

$CP_1 = O_1 =$ first offset

$\angle CT_1P_1 = \alpha$ in radian

$\angle T_1OP_1 = 2\alpha$ in radian



Assuming

$$\text{Chord } T_1P_1 = \text{arc } T_1P_1 = R \times 2\alpha$$

$$\Rightarrow \boxed{\alpha = \frac{T_1P_1}{2R}}$$

Again chord $CP_1 \sim$ arc CP_1

$$\therefore O_1 = CP_1 = T_1P_1 \times \alpha$$

$$\Rightarrow \boxed{O_1 = \frac{T_1P_1^2}{2R} = \frac{b_1^2}{2R}}$$

————— (1)

→ Let P_2 be next point on curve, P_1C_1 is full chord = d_2

Now $P_1C_1 = P_1P_2 \sim b_2$

and chord $CP_2 = \text{arc } CP_2 = O_2$

→ At P_1 a tangent is drawn which meet AB at D and C_1P_2 at M_1 .

Here

$$\angle C_1P_1M_1 = \angle DP_1T_1$$

$$\angle DP_1T_1 = \angle DT_1P_1$$

$$\angle CP_1M_1 = \angle DP_1T_1 = \angle DT_1P_1 = \angle CT_1P_1$$

So ΔCT_1P_1 and $\Delta C_1P_1M_1$ are similar

$$\frac{C_1M_1}{P_1C_1} = \frac{CP_1}{T_1P_1} \Rightarrow \frac{C_1M_1}{b_2} = \frac{O_1}{b_1}$$

$$\Rightarrow C_1M_1 = \frac{b_2 O_1}{b_1} = \frac{b_2}{b_1} \times \frac{b_1^2}{2R}$$

$$\Rightarrow \boxed{C_1M_1 = \frac{b_1 b_2}{2R}}$$

Also M_1P_2 is the offset from the tangent at P_1
so, according to eq. (1)

$$M_1P_2 = \frac{(P_1P_2)^2}{2R} = \frac{b_2^2}{2R}$$

$$\therefore O_2 = C_1P_2 = C_1M_1 + M_1P_2$$

$$\Rightarrow O_2 = \frac{b_1 b_2}{2R} + \frac{b_2^2}{2R}$$

$$\Rightarrow \boxed{O_2 = \frac{b_2 (b_1 + b_2)}{2R}}$$

→ Similarly

$$O_3 = \frac{b_3 (b_2 + b_3)}{2R} = \frac{b_3^2}{R}$$

$$O_4 = \frac{b_4 (b_3 + b_4)}{2R} = \frac{b_4^2}{R}$$

$$\vdots$$

$$O_n = \frac{b_n (b_{n-1} + b_n)}{2R}$$

where b_n = final sub chord, b_{n-1} = last full chord.

Q Two tangents intersecting at a chainage of 1000 m. The deflection angle being 30° . Calculate all the necessary data for setting out a circular curve of Radius 200 m by the method of offsets from the chord produced, taking a peg interval of 20 m.

Rankine's Method of Tangent Angles

→ AB and BC are tangents intersecting at B, ϕ is deflection angle and T_1 and T_2 are tangent points.

P_1 = first point on the curve

$T_1 P_1 = l_1$ = length of first chord

δ_1 = deflection angle for first chord

R = Radius of curve

Δ_n = total deflection for the chords

Now

$$\angle T_1 O P_1 = 2 \angle B T_1 P_1 = 2 \delta_1$$

Chord $T_1 P_1$ & arc $T_1 P_1$

$$\text{Also } \frac{\angle T_1 O P_1}{l_1} = \frac{360^\circ}{2\pi R}$$

$$\Rightarrow 2\delta_1 = \frac{360^\circ l_1}{2\pi R}$$

$$\Rightarrow \delta_1 = \frac{360^\circ \times l_1}{2 \times 2\pi R} \text{ degrees}$$

$$= \frac{360 \times 60 l_1}{2 \times 2 \times \pi \times R} \text{ min}$$

$$= \frac{1718.9 l_1}{R} \text{ min}$$

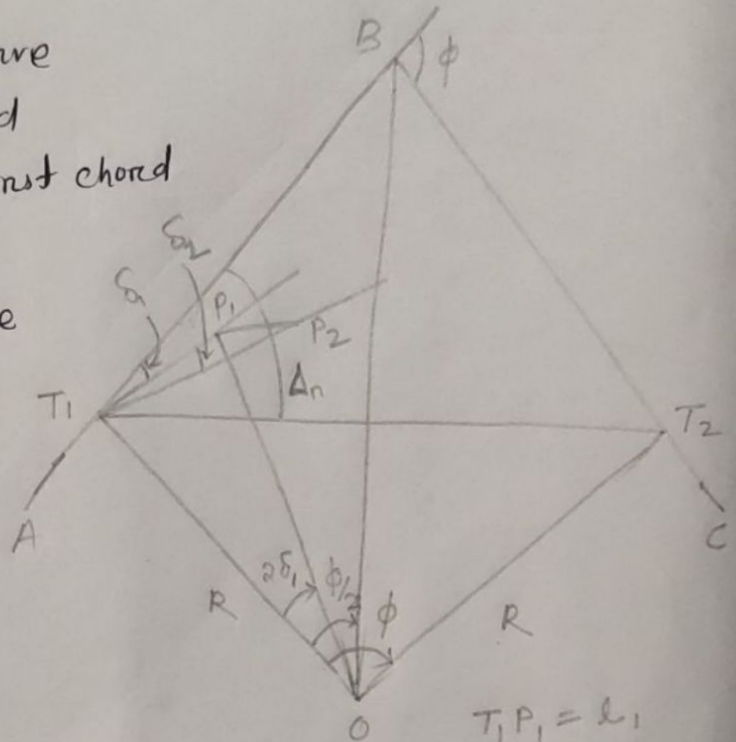
Similarly

$$\delta_2 = \frac{1718.9 l_2}{R}$$

$$\delta_3 = \frac{1718.9 l_3}{R}$$

⋮

$$\delta_n = \frac{1718.9 l_n}{R}$$



$$T_1 P_1 = l_1$$

$$P_1 P_2 = l_2$$

Again Degree of curve D is given

$$\delta_1 = \frac{D \times l_1}{60} \text{ degrees}$$

$$\delta_2 = \frac{D \times l_2}{60}$$

⋮

$$\delta_n = \frac{D \times l_n}{60}$$

check

$$\delta_1 + \delta_2 + \delta_3 + \delta_4 + \dots + \delta_n = \Delta_n = \phi/2$$

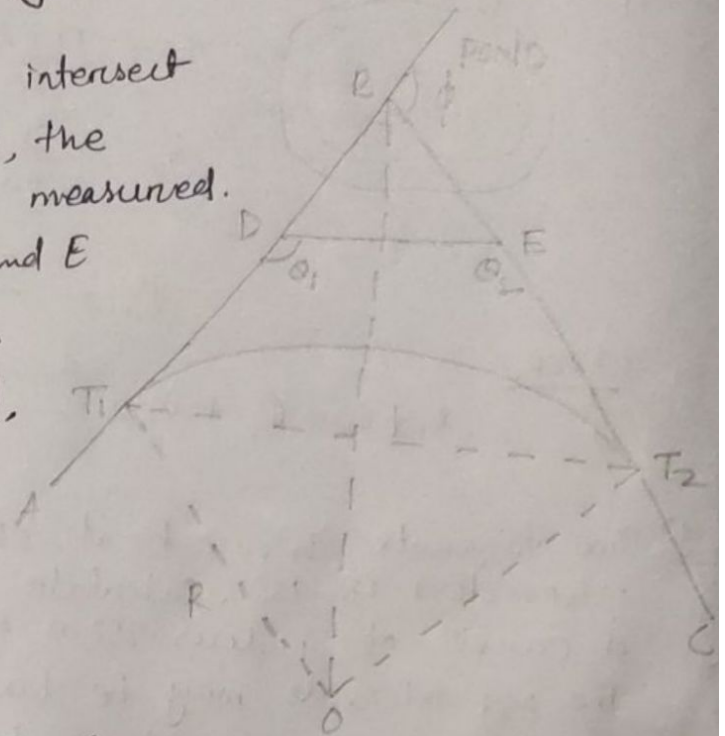
Q Two tangents intersect at chainage 1250 m. The angle of intersection is 150° . Calculate all data necessary for setting out a curve of radius 250 m by the deflection angle Method. The peg intervals may be taken as 20 m. Prepare a setting out table when the least count of the vernier is 20". Calculate the data for field checking.

2.5 = Obstacles in curve ranging: Point of intersection inaccessible

Let two straight lines AB and BC intersect at B, which is inaccessible. So, the deflection angle ϕ can not be measured.

→ Let us select two points D and E along AB and BC respectively.

→ The distance DE is measured, and the angle θ_1 and θ_2 are measured by theodolite.



Now,

$$\angle BDE = 180 - \theta_1$$

$$\angle BED = 180 - \theta_2$$

$$\text{Angle of intersection } I = 180 - (180 - \theta_1 + 180 - \theta_2)$$

$$= \theta_1 + \theta_2 - 180^\circ$$

$$\therefore \phi = 180^\circ - I = 180^\circ - (\theta_1 + \theta_2 - 180^\circ)$$

$$\phi = 360 - (\theta_1 + \theta_2)$$

Apply sine rule in $\triangle BDE$

$$\frac{BD}{\sin(180 - \theta_2)} = \frac{BE}{\sin(180 - \theta_1)} = \frac{DE}{\sin(\theta_1 + \theta_2 - 180^\circ)}$$

$$\therefore BD = DE \frac{\sin(180 - \theta_2)}{\sin(\theta_1 + \theta_2 - 180^\circ)}$$

$$BE = DE \frac{\sin(180 - \theta_1)}{\sin(\theta_1 + \theta_2 - 180^\circ)}$$

$$BT_1 = R \tan\left(\frac{360 - (\theta_1 + \theta_2)}{2}\right)$$

$$DT_1 = BT_1 - BD \quad \text{and} \quad ET_2 = BT_2 - BE$$

→ Now the tangent points are fixed by measuring distances DT_1 and ET_2 . When T_1 & T_2 are fixed, the curve can be set out by any method.

BASICS ON SCALE AND BASICS OF MAP:

3.1 Fractional or Ratio Scale, Linear Scale, Graphical Scale

3.2 What is Map, Map Scale and Map Projections

3.3 How Maps Convey Location and Extent

3.4 How Maps Convey characteristics of features

3.5 How Maps Convey Spatial Relationship

3.5.1 Classification of Maps

3.5.1 Physical Map

3.5.2 Topographic Map

3.5.3 Road Map

3.5.4 Political Map

3.5.5 Economic & Resources Map

3.5.6 Thematic Map

3.5.7 Climate Map

3.1 Fractional or Ratio Scale, Linear Scale, Graphical Scale

SCALE

Naturally it is impossible for real world features to be drawn on the map as large as their true size. Therefore in order to represent the real world, maps are made to a specific scale. Map scale is defined as the ratio of the distance between two points on the map to the corresponding distance on the ground.

A linear scale, also called a bar scale, scale bar, graphic scale, or graphical scale, is a means of visually showing the scale of a map, nautical chart, engineering drawing, or architectural drawing. A scale bar is common element of map layouts.

Fractional Scale

- The fractional scale or the representative scale expresses the scale of a map as a fraction or ratio.
– 1/24,000 or 1:24,000

$$\begin{aligned} \frac{\text{Distance on the Map}}{\text{Distance on the Ground}} &= \frac{2 \text{ cm}}{1 \text{ km}} = \frac{2 \text{ cm}}{100\,000 \text{ cm}} \\ &= \frac{1}{50\,000} \\ &= \mathbf{1/50\,000 \text{ Scale}} \end{aligned}$$

A linear scale is a line which is divided into equal parts. It is used on maps to show the relationship between a particular distance on a map and the actual distance on the earth. A linear scale is also called a bar scale, scale bar or graphic scale.

3.2 What is Map

A map is a symbolic representation of selected characteristics of a place, usually drawn on a flat surface. Maps present information about the world in a simple, visual way. They teach about the world by showing sizes and shapes of countries, locations of features, and distances between places. Maps can show distributions of things over Earth, such as settlement patterns. They can show exact locations of houses and streets in a city neighborhood.

Map Scale

All maps are scale models of reality. A map's scale indicates the relationship between the distances on the map and the actual distances on Earth. This relationship can be expressed by a graphic scale, a verbal scale, or a representative fraction.

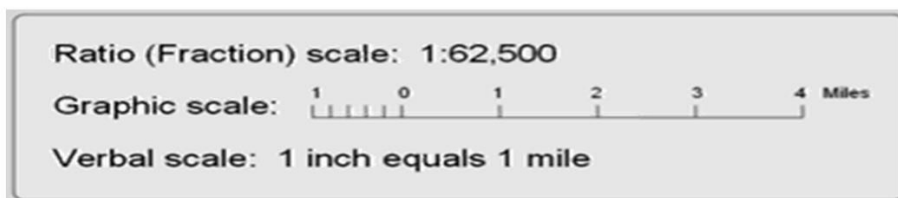
The most common type of graphic scale looks like a ruler. Also called a bar scale, it is simply a horizontal line marked off in miles, kilometers, or some other unit measuring distance.

The verbal scale is a sentence that relates distance on the map to distance on Earth. For example, a verbal scale might say, "one centimeter represents one kilometer" or "one inch represents eight miles."

The representative fraction does not have specific units. It is shown as a fraction or ratio—for example, $1/1,000,000$ or $1:1,000,000$. This means that any given unit of measure on the map is equal to one million of that unit on Earth. So, 1 centimeter on the map represents 1,000,000 centimeters on Earth, or 10 kilometers. One inch on the map represents 1,000,000 inches on Earth, or a little less than 16 miles.

The size of the area covered helps determine the scale of a map. A map that shows an area in great detail, such as a street map of a neighborhood, is called a large-scale map because objects on the map are relatively large. A map of a larger area, such as a continent or the world, is called a small-scale map because objects on the map are relatively small.

Today, maps are often computerized. Many computerized maps allow the viewer to zoom in and out, changing the scale of the map. A person may begin by looking at the map of an entire city that only shows major roads and then zoom in so that every street in a neighborhood is visible.



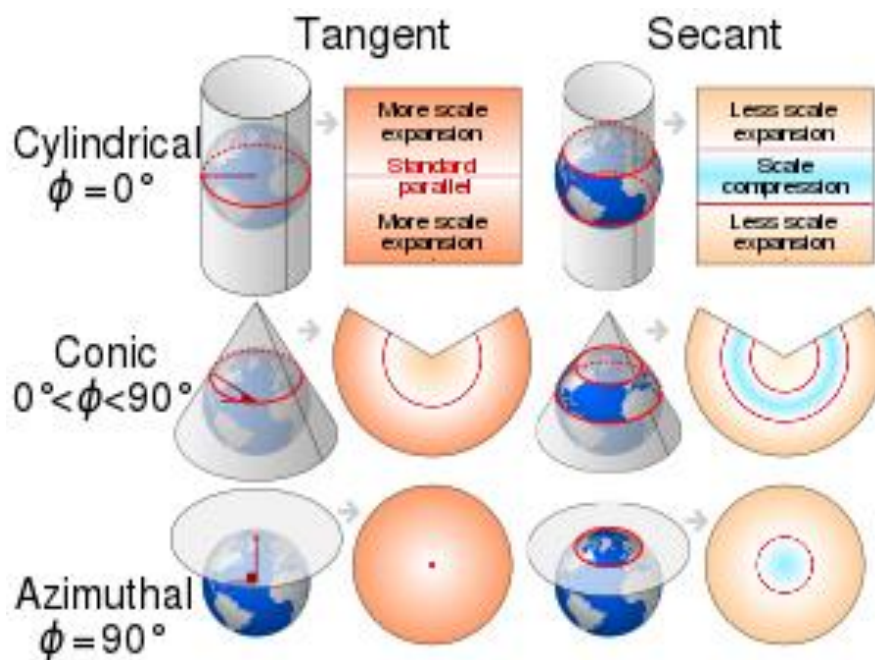
Map Projections

A map projection is a way to flatten a globe's surface into a plane in order to make a map. This requires a systematic transformation of the latitudes and longitudes of locations from the surface of the globe into locations on a plane. All projections of a sphere on a plane necessarily distort the surface in some way and to some extent. Depending on the purpose of the map, some distortions

are acceptable and others are not; therefore, different map projections exist in order to preserve some properties of the sphere-like body at the expense of other properties.

The creation of a map projection involves two steps:

1. Selection of a model for the shape of the Earth or planetary body (usually choosing between a sphere or ellipsoid). Because the Earth's actual shape is irregular, information is lost in this step.
2. Transformation of geographic coordinates (longitude and latitude) to Cartesian (x,y) or polar plane coordinates. In large-scale maps, Cartesian coordinates normally have a simple relation to eastings and northings defined as a grid superimposed on the projection. In small-scale maps, eastings and northings are not meaningful, and grids are not superimposed.



3.5 How Maps Convey Spatial Relationship

Maps help convey geographic relationships that can be interpreted and analyzed by map readers. Relationships that are based on location are referred to as spatial relationships. Here are some examples.

1. Which geographic features *connect* to others (for example, Water Street connects with 18th Ave.)
2. Which geographic features are *adjacent* (contiguous) to others (for example, The city park is adjacent to the university.)
3. Which geographic features are *contained within* an area (for example, The building footprints are contained within the parcel boundary.)
4. Which geographic features *overlap* (for example, The railway crosses the freeway.)
5. Which geographic features are *near* others (proximity) (for example, The Courthouse is near the State Capitol.)
6. The feature geometry *is equal to* another feature (for example, The city park is equal to the historic site polygon.)
7. The *difference* in elevation of geographic features (for example, The State Capitol is uphill from the water.)
8. The feature is *along* another feature (for example, The bus route follows along the street network.)

3.5.1 Classification of Maps

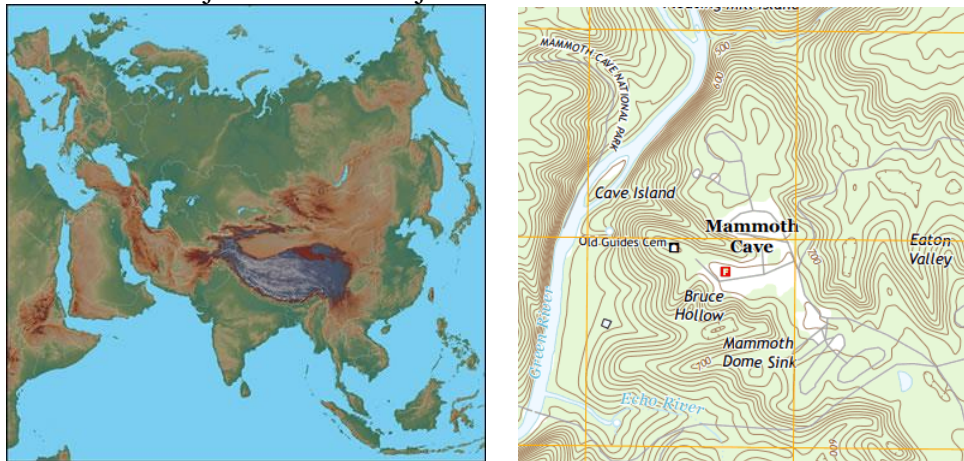
Maps are classified in to following catagories

3.5.1 Physical Map

Physical maps are designed to show the natural landscape features of Earth. They are best known for showing topography, either by colors or as shaded relief. Physical maps often have a green to brown to gray color scheme for showing the elevation of the land. Darker greens are used for near-sea-level elevations, with the color grading into tans and browns as elevations increase. The color gradient often terminates in shades of gray for the highest elevations.

Rivers, lakes, seas and oceans are usually shown in blue, often with a light blue color for the most shallow areas and darkening in a gradient or by intervals for areas of deeper water. Glaciers and ice caps are shown in white colors.

Physical maps usually show the most important political boundaries, such as state and country boundaries. Major cities and major roads are often shown.



3.5.2 Topographic Map

Topographic maps are reference maps that show the shape of Earth's surface. They usually do this with lines of equal elevation known as "contour lines", but elevation can also be shown using colors, color gradients, shaded relief and a number of other methods.

Topographic maps are frequently used by hunters, hikers, skiers, and others seeking outdoor recreation. They are also essential tools of the trade for geologists, surveyors, engineers, construction workers, landscape planners, architects, biologists and many other professions - especially people in the military.

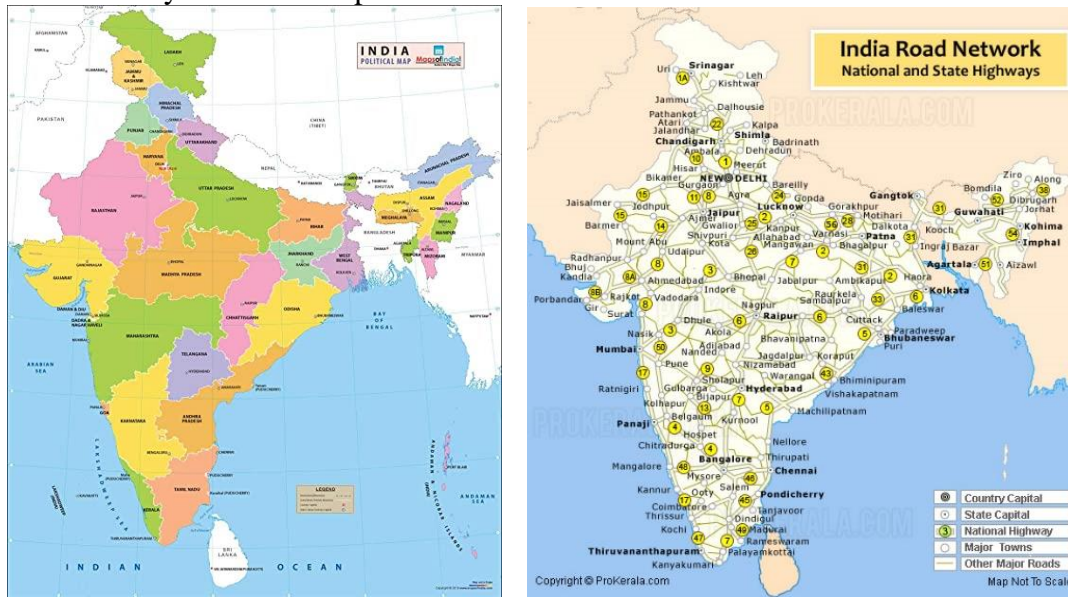
Topographic maps also show other important natural features such as lakes, rivers and streams. Their locations are determined by topography, making them important natural elements of topographic maps.

Important cultural features are also shown on topographic maps. These include roads, trails, buildings, place names, bench marks, cemeteries, churches, schools and much more. A standardized set of special symbols has been developed for this use.

Topographic maps have traditionally been printed on large sheets of paper with their four boundaries being lines of longitude and latitude.

3.5.3 Road Map

A road map, route map, or street map is a map that primarily displays roads and transport links rather than natural geographical information. It is a type of navigational map that commonly includes political boundaries and labels, making it also a type of political map. In addition to roads and boundaries, road maps often include points of interest, such as prominent businesses or buildings, tourism sites, parks and recreational facilities, hotels and restaurants, as well as airports and train stations. A road map may also document non-automotive transit routes, although often these are found only on transit maps.



3.5.4 Political Map

"Political maps" are among the most widely used reference maps. They are mounted on the walls of classrooms throughout the world. They show the geographic boundaries between governmental units such as countries, states, and counties. They show roads, cities and major water features such as oceans, rivers and lakes.

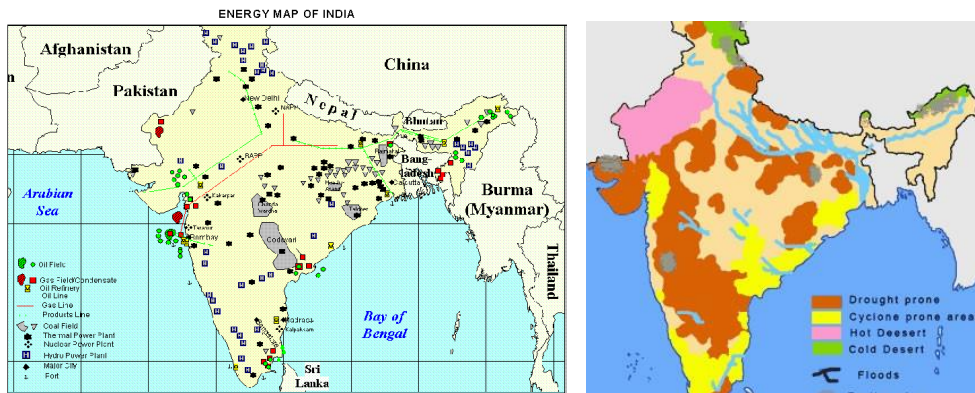
Political maps help people understand the geography of the world. They are usually the first type of map that students are introduced to in school. They are also known as "reference maps" because people refer to them again and again as they have questions.

Political maps are often printed on paper or another physical medium, but they can also be produced in digital form, suitable for viewing online.

The maps most commonly seen in classrooms and offices are political maps of the world, countries and continents. They are often annotated with push pins, sticky notes, photographs, marker flags and string to show the travels of a family, locations of a business, or other locations and activities worthy of display.

3.5.5 Economic & Resources Map

Economic and Resource Maps display information based on an area's natural resources available or economic activity. These maps are helpful in finding out where companies should mine and search for particular resources, determining where the best location to ship resources from is, and where you might be able to afford to live based on your salary or the types of jobs available. By looking at what resources are available it also helps determine which types of industries would thrive in that area.



3.5.6 Climate Map

A climate map shows information about the climate of an area. These maps can show things like the specific climatic zones of an area based on the temperature, the amount of snow an area receives, or the average number of cloudy days. These maps normally use colors to show different climatic areas.

Climatic map, chart that shows the geographic distribution of the monthly or annual average values of climatic variables i.e., temperature, precipitation, relative humidity, percentage of possible sunshine, insolation, cloud cover, wind speed and direction, and atmospheric pressure over regions ranging in area from a few tens of square kilometres to global.

3.5.7 Thematic map

A thematic map is a type of map that portrays the geographic pattern of a particular subject matter (theme) in a geographic area. This usually involves the use of map symbols to visualize selected properties of geographic features that are not naturally visible, such as temperature, language, or population.

In this, they contrast with general reference maps, which focus on the location (more than the properties) of a diverse set of physical features, such as rivers, roads, and buildings. Alternative names have been suggested for this class, such as special-subject or special-purpose maps, statistical maps, or distribution maps, but these have generally fallen out of common usage.

Survey of India topographical maps:
Reference scheme of Open Series
Map (OSM)

Anupam Das
Panihati Mahavidyalaya

❑ 'Open Series Map' have been introduced as per the [National Map Policy of 2005](#) by [Survey of India](#).

❑ Enhanced by the latest technology (RS and GIS) to meet the multidisciplinary needs of national security, suitable national development and new information market.

❑ The OSM numbering system based on [International Map of the World \(IMW\)](#) is used.

❑ The '[International Map of the World \(IMW\)](#)' was a project which started in 1913 to create a complete map of the world as per internationally agreed and consistent specifications

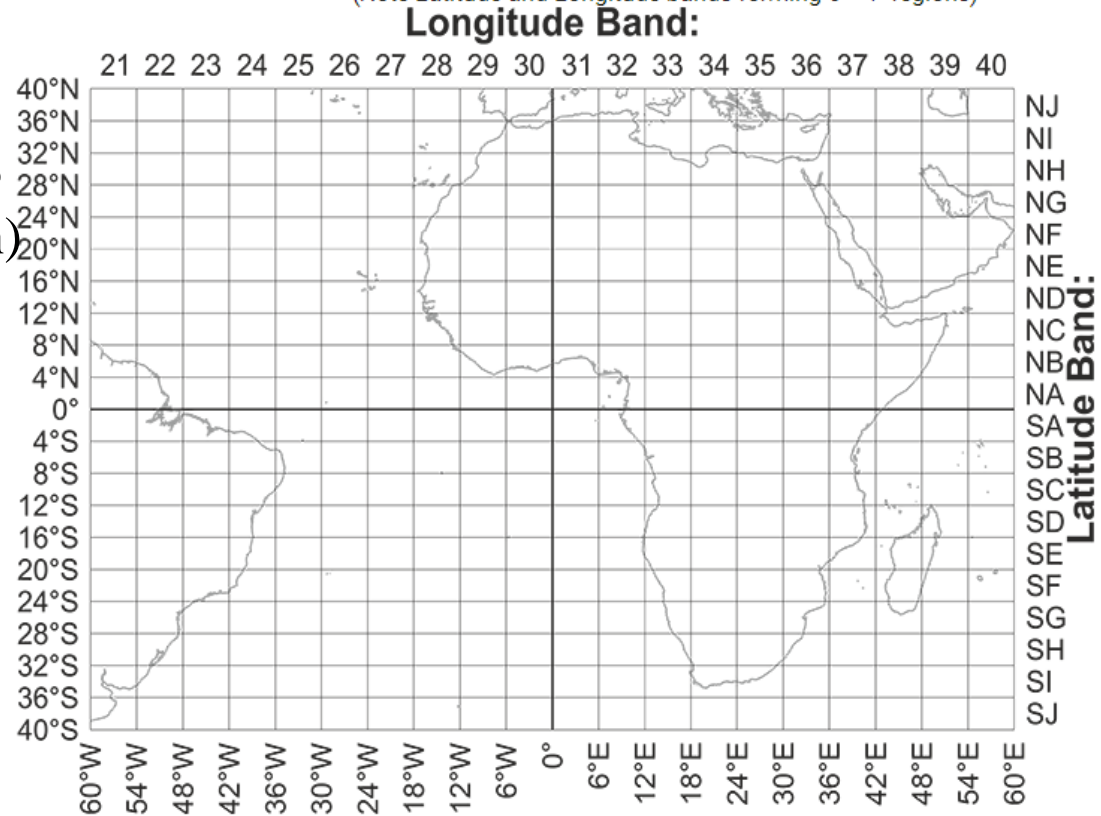
The International Map of the World series

Map numbering is of the form '**NA-12A**'

- The first letter is either '**N**' or '**S**' to denote the hemisphere (North/South) with respect to the equator.

- A second letter denotes the 4° latitude band with alphabet increasing as latitude moves away from equator. So sheets between 12°N to 8°N would be '**NC**' and between 4°S to 8°S would be '**SB**'.

International Map of the World scheme for a part of the world:
(Note Latitude and Longitude bands forming 6°×4° regions)



The next number denotes the 6° longitude band with numbering starting at 1 from 180°W (i.e. 1 between 180°W and 174°W) going on to 60 (i.e. between 174°E-180°E). So sheet between 72° to 78°E and 12°N to 8°N will be '**NC-43**'. Similarly between 132°W to 126°W and 4°S to 8°S would be '**SB-9**'. The longitude band span increased to 12° from 60° latitude and to 24° from 76° latitude due to the decrease in physical span of longitude band.

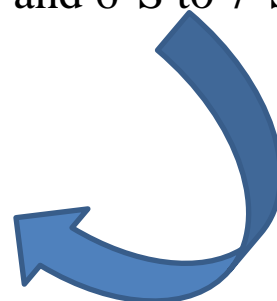
•Each $6^\circ \times 4^\circ$ rectangle is further subdivided into 24 squares of $1^\circ \times 1^\circ$. Each square is indicated serially by an alphabet increasing first towards east and then towards south, starting with 'A'.

•So for sheet between 74° to 75° E and 11° N to 10° N we get **NC-43I**:

12°N	A	B	C	D	E	F	
11°N	G	H	I	J	K	L	
10°N	M	N	O	P	Q	R	
9°N	S	T	U	V	W	X	
8°N							
	72°E	73°E	74°E	75°E	76°E	77°E	78°E

4°S	A	B	C	D	E	F	
5°S	G	H	I	J	K	L	
6°S	M	N	O	P	Q	R	
7°S	S	T	U	V	W	X	
8°S							
	132°W	131°W	130°W	129°W	128°W	127°W	126°W

For sheet between 128° W to 127° W and 6° S to 7° S we get **SB-9Q**:

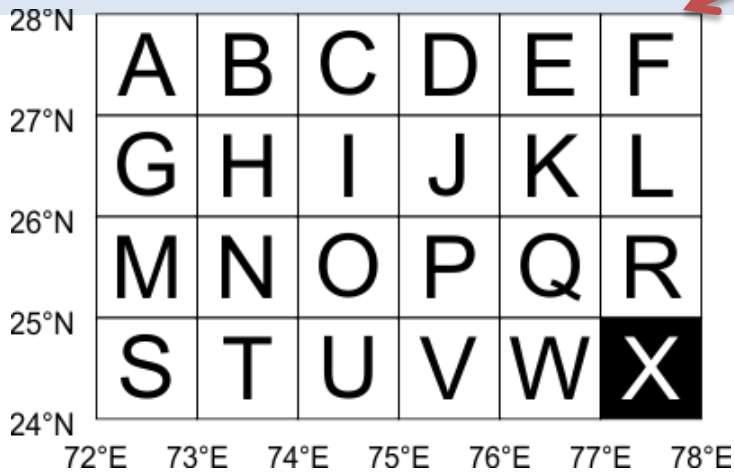


OSM NUMBERING SYSTEM

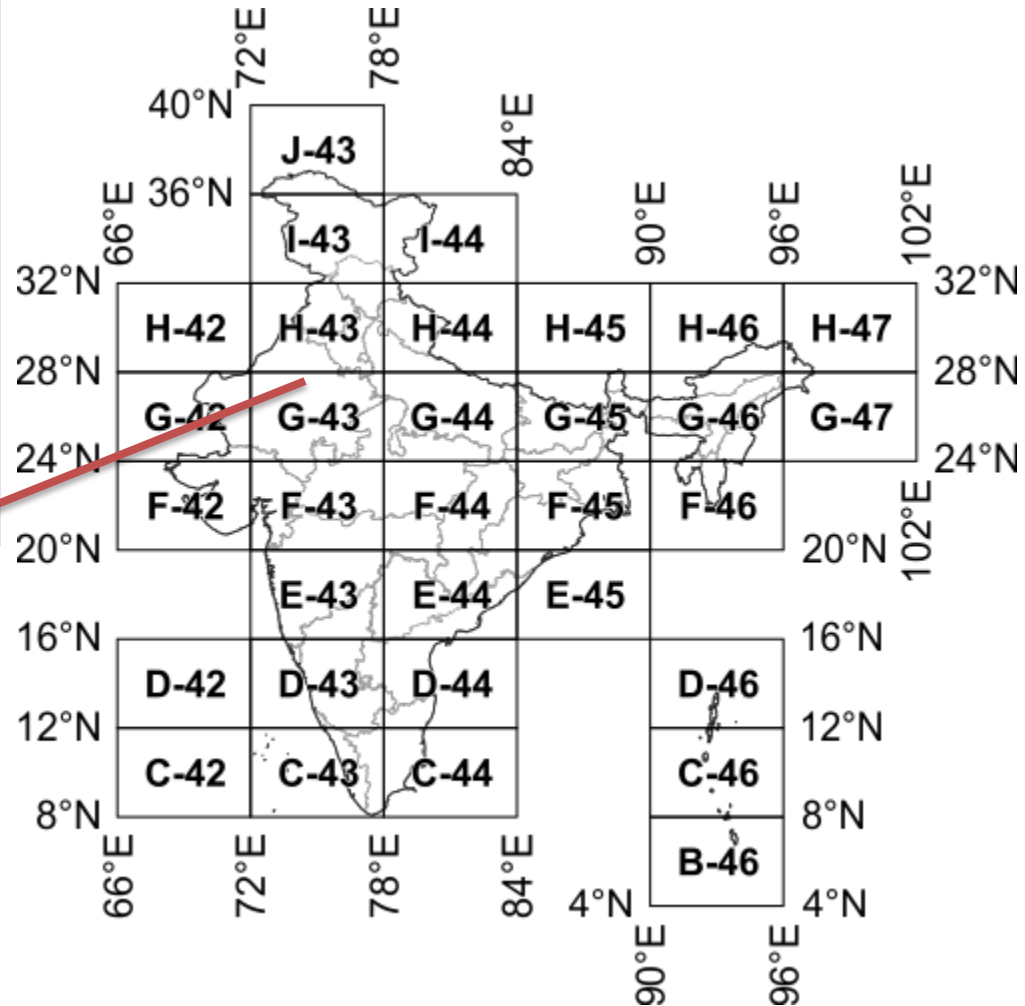
The next alphabet and number of the IMW map number denotes the $6^\circ \times 4^\circ$ region of the IMW series. So sheet with Kalyanpur (77.65489°E 24.11981°N) would be in '**G-43**' (from NG-43):

Since the IMW map number for India will always start with 'N' (India being in the northern hemisphere), the first letter is omitted.

Each $6^\circ \times 4^\circ$ rectangle is further subdivided into **24 squares of $1^\circ \times 1^\circ$** . Each square is indicated serially by an alphabet increasing first towards east and then towards south, starting with 'A'. So sheet for Kalyanpur (77.65489°E 24.11981°N) falls within '**G-43X**':



DEGREE SHEET: G43X
1:250,000

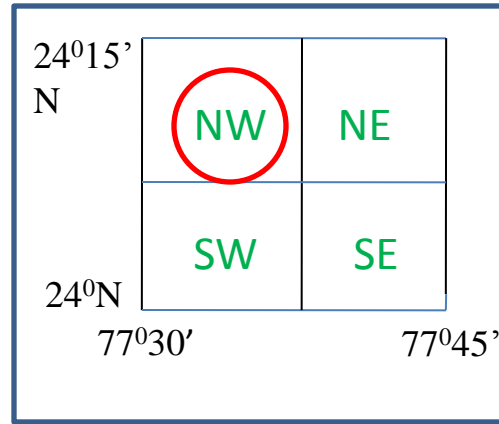


Million sheets, 1: 1000,000

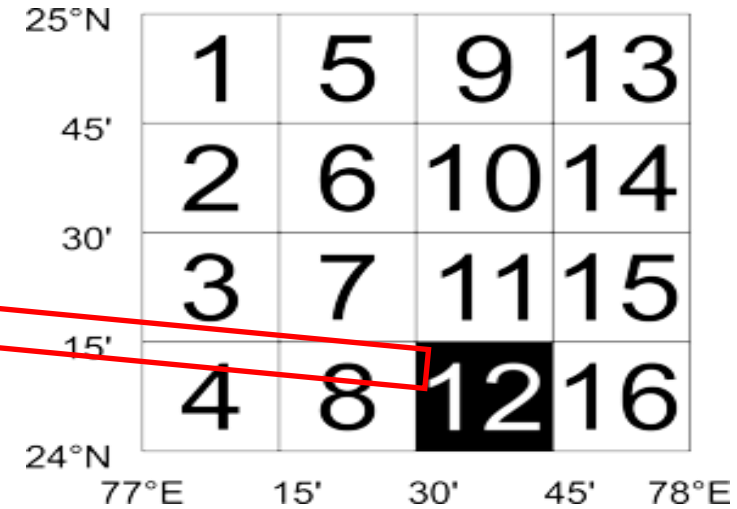
Each $1^\circ \times 1^\circ$ square is further divided into 16 squares of $15' \times 15'$ (15 minutes \times 15 minutes). Each square is indicated serially by a number increasing first towards south and then towards east, starting with '1' (similar to the system adopted in [India and Adjacent Countries](#)). So for the map sheet for Kalyanpur ($77^\circ 39.293'E$ $24^\circ 7.187'N$) would be '**G-43X-12**':

A 15' minute sheet can be divided in *two types*:

First, each sheet contains 4 quadrant sheets ($7'30'' \times 7'30''$) on 1:25,000 scale and designated as NW, NE, SE and SW.



Quadrant Sheet: G43X12NW
1:25,000



15' Sheet: G43X12
1:50,000

Second, each contains 25 sheets of dimension (3' X 3') on 1:10,000 scale and are designated by alphabets, A-Y.

24°15' N	A	F	K	P	U	
24°12'						
24°09'	B	G	L	Q	V	
24°06'	C	H	M	R	W	
24°03'	D	I	N	S	X	
24°0' N	E	J	O	T	Y	
	77°30'E	77°33'	77°36'	77°39'	77°42'	77°45'

3' Sheet: G43X12U
1:10,000

25°N	1	5	9	13	
45'	2	6	10	14	
30'	3	7	11	15	
15'	4	8	12	16	
24°N	77°E	15'	30'	45'	78°E

	1	6	11	16	21
	2	7	12	17	22
	3	8	13	18	23
	4	9	14	19	24
	5	10	15	20	25

77°30'E 77°30'36" 77°31'12" 77°31'48" 77°32'24" 77°33'E

Each 3'-Sheet contains 25 sheets of (36" x 36") on 1:2000 scale and are designated by numerals, 1-25.

☐ These are the largest scale maps published by the SOI, larger than cadastral maps (1:4000).

☐ LS sheets

4.2 Defence Series Maps (DSMs)

Survey of India (SOI) brings out two series of maps through the National Map Policy, 2005.

Defence Series Maps (DSMs) - These topographical maps (on Everest/WGS-84 Datum and Polyconic/UTM Projection) are on various scales (with heights, contours and full content without dilution of accuracy). These maps mainly cater for defence and national security requirements. This series of maps (in analogue or digital forms) for the entire country are classified by the Ministry of Defence.

Open Series Maps (OSMs) - OSMs are brought out exclusively by SOI, primarily for supporting development activities in the country. OSMs bear different map sheet numbers and are in UTM Projection on WGS-84 datum. Each of these OSMs (in both hard copy and digital form) become 'Unrestricted'.

With Defense Mapping, you can:

Reduce the time needed to compile and maintain military data and maps.

Capture and distribute best management practices throughout the organization to ensure data consistency from site to site.

Simplify the production and publication of your final map using the included library of cartographic symbols and map templates.

Implement in-process quality assurance by leveraging relational geodatabase models, extended attribute validation rules, and automated geometry validation.

Efficiently perform database maintenance, quality control, and high-quality cartographic output for defense-specific products.

Standardize cartographic production with efficiency-focused map series design and layout tools, rule-based symbology, and cartographic editing tools.

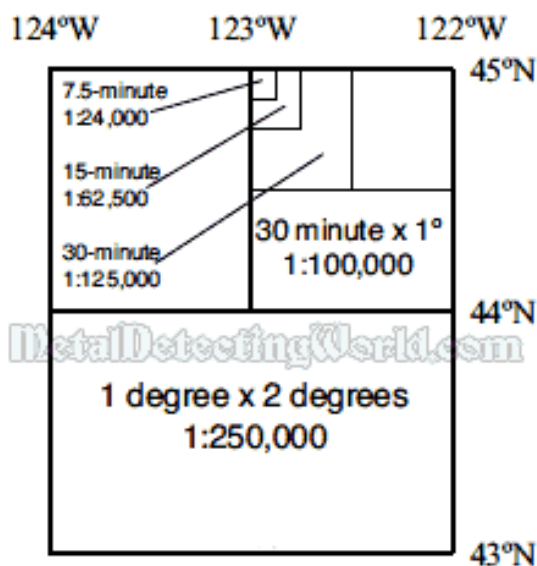
Roads, metalled : according to importance; distance stone	
Roads, unmetalled : according to importance; bridge	
Cart-track, Pack-track and pass. Foot-path with bridge	
Streams : with track in bed; undefined. Canal	
Dams: masonry or rock-filled; earthwork, Weir	
River dry with water channel; with islands and rocks. Tidal river	
Swamp, Reeds	
Wells : lined; unlined. Spring. Tanks : perennial; dry	
Embankments : road or rail	
Railway, broad gauge : double; single with station; under construction	
Railway other gauges : double; single with distance stone; under constrn.	
Light Railway or tramway, Telegraph line. Cutting with tunnel	
Contours, Cliffs	
Sand features (1) flate (2) sand hills (permanent) (3) dunes (shifting)	
Towns or Villages : inhabited ; deserted. Fort	
Huts : permanent; temporary. Tower Antiquities	
Temple. Chhatri. Church. Mosque. Idgah. Tomb. Graves.	
Lighthouse, Lightship. Buoys : lighted ; unlighted. Anchorage	
Mine. Vine on trellis. Grass. Scrub	
Palms : Palmyra; other. Plantain. Conifer. Bamboo. Other trees.	
Boundary, international	
Boundary, state : demarcated; undemarcated	
Boundary, district : subdivision, tahsil or taluk; forest	
Boundary, pillars : surveyed; unlocated; village trijunction	
Heights, triangulated : station; point; approximate	
Bench-mark : geodetic; tertiary; canal	
Post office. Telegraph Office. Combined office. Police station.	
Bungalows; dak or travellers; inspection. Rest-house	
Circuit house. Camping ground.	
Forest : reserved; protected	
<p>A number of methods have been used to show the relief features of the Earth's surface on maps, over the years. These methods include hachure, hill shading, layer tints, benchmarks and spot heights and contours. However, contours and spot heights are predominantly used to depict the relief of an area on all topographical maps.</p>	

Figure 11.1 Conventional Signs and Symbols

4.3.1 Quadrangle names

A "quadrangle" is a topographic map produced by the United States Geological Survey (USGS) covering the United States. The maps are usually named after local physiographic features. The shorthand "quad" is also used, especially with the name of the map; for example, "the Ranger Creek, Texas quad". From approximately 1947-1992, the USGS produced the 7.5 minute series, with each map covering an area one-quarter of the older 15-minute quad series, which it replaced. A 7.5 minute quadrangle map covers an area of 49 to 70 square miles (130 to 180 km²). Both map series were produced via photogrammetric analysis of aerial photography using stereoplotters supplemented by field surveys.

On a quadrangle map, the north and south limits are not straight lines, but are actually curved to match Earth's lines of latitude on the standard projection. The east and west limits are usually not parallel as they match Earth's lines of longitude.



The USGS topographic quadrangles come in a variety of scales from 1:500,000 to larger scales (i.e. 1:24,000 scale). Each scale may be an appropriate base map for a geologic map, but the scale of map base used should be appropriate to the detail provided in a geologic map.

4.3.2 Latitude

Latitude is the measurement of distance north or south of the Equator. It is measured with 180 imaginary lines that form circles around the Earth east-west, parallel to the Equator. These lines are known as parallels. A circle of latitude is an imaginary ring linking all points sharing a parallel.

The Equator is the line of 0 degrees latitude. Each parallel measures one degree north or south of the Equator, with 90 degrees north of the Equator and 90 degrees south of the Equator. The latitude of the North Pole is 90 degrees N, and the latitude of the South Pole is 90 degrees S.

Like the poles, some circles of latitude are named. The Tropic of Cancer, for instance, is 23 degrees 26 minutes 21 seconds N— $23^{\circ} 26' 21''$ N. Its twin, the Tropic of Capricorn, is $23^{\circ} 26' 21''$ S. The tropics are important geographic locations that mark the northernmost and southernmost latitudes where the sun can be seen directly overhead during a solstice.

One degree of latitude, called an arcdegree, covers about 111 kilometers (69 miles). Because of the Earth's curvature, the farther the circles are from the Equator, the smaller they are. At the North and South Poles, arcdegrees are simply points.

Degrees of latitude are divided into 60 minutes. To be even more precise, those minutes are divided into 60 seconds. One minute of latitude covers about 1.8 kilometers (1.1 miles) and one second of latitude covers about 32 meters (105 feet).

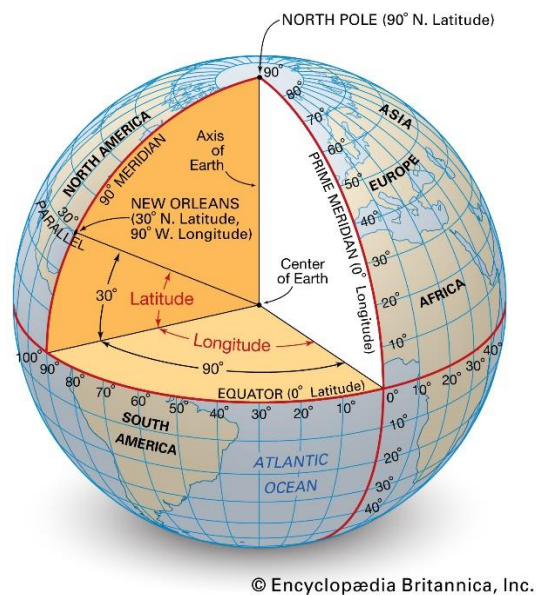
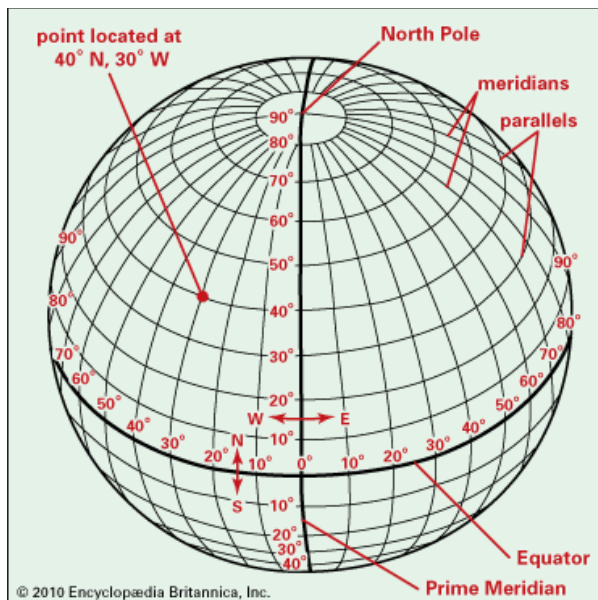
Longitude

Longitude is the measurement east or west of the prime meridian. Longitude is measured by imaginary lines that run around the Earth vertically (up and down) and meet at the North and South Poles. These lines are known as meridians. Each meridian measures one arcdegree of longitude. The distance around the Earth measures 360 degrees.

The meridian that runs through Greenwich, England, is internationally accepted as the line of 0 degrees longitude, or prime meridian. The antimeridian is halfway around the world, at 180 degrees. It is the basis for the International Date Line.

Half of the world, the Eastern Hemisphere, is measured in degrees east of the prime meridian. The other half, the Western Hemisphere, in degrees west of the prime meridian.

Degrees of longitude are divided into 60 minutes. Each minute of longitude can be further divided into 60 seconds. For example, the longitude of Paris, France, is $2^{\circ} 29' E$ (2 degrees, 29 minutes east). The longitude for Brasilia, Brazil, is $47^{\circ} 55' W$ (47 degrees, 55 minutes west).



UTM's

UTM is the acronym for Universal Transverse Mercator, a plane coordinate grid system named for the map projection on which it is based (Transverse Mercator). The UTM system consists of 60 zones, each 6-degrees of longitude in width. The zones are numbered 1-60, beginning at 180-degrees longitude and increasing to the east.

The Universal Transverse Mercator (UTM) conformal projection uses a 2-dimensional Cartesian coordinate system to give locations on the surface of the Earth.

The limits of each zone are 84° N and 80° S, with the division between north and south zones occurring at the equator.

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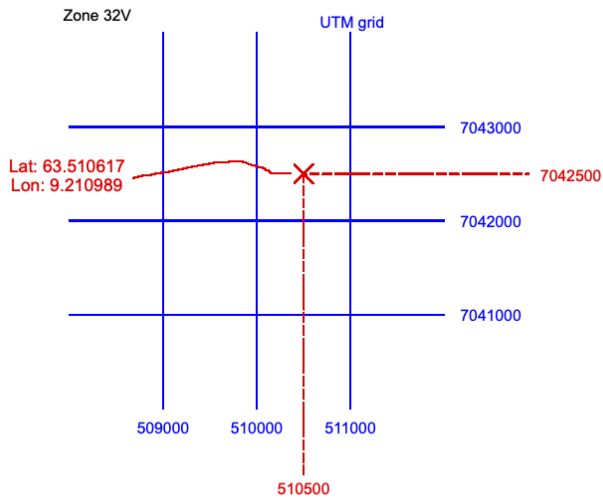
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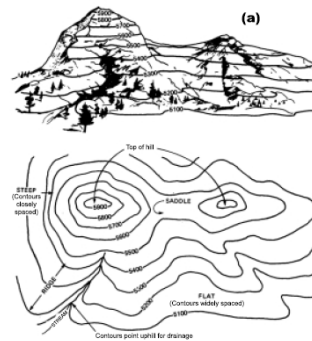
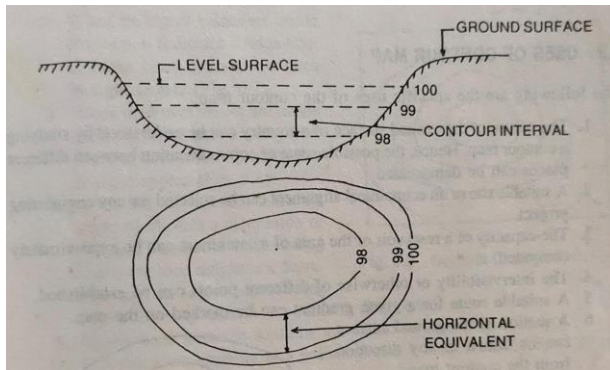
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4.3.5 Magnetic Declination

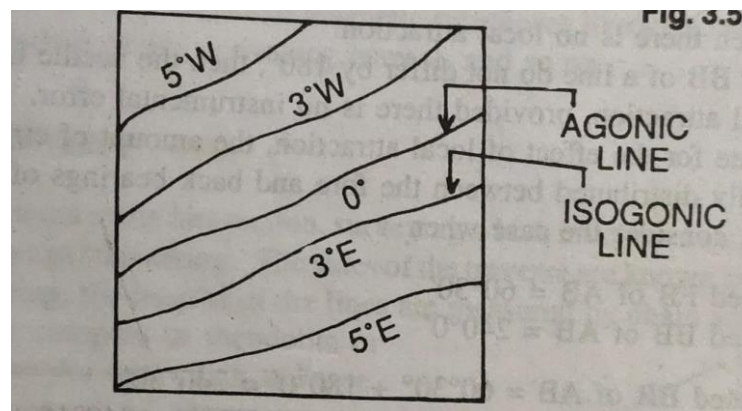
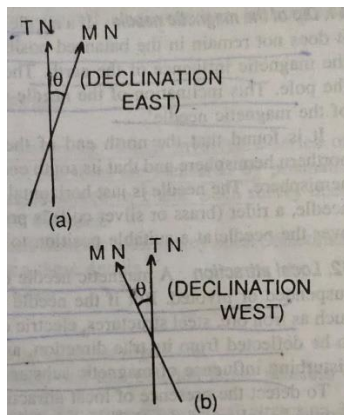
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4.3.6 Public Land Survey System

The Public Land Survey System (PLSS) is the surveying method developed and used in the United States to plat, or divide, real property for sale and settling.

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4.3.7 Field Notes

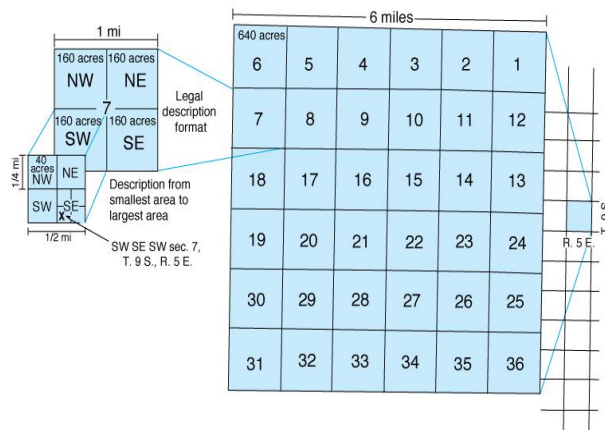
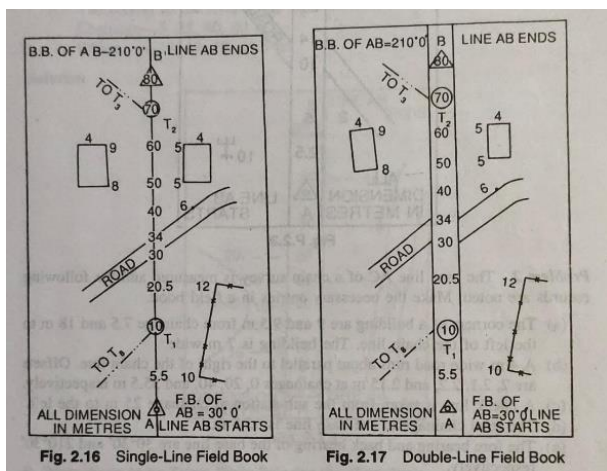
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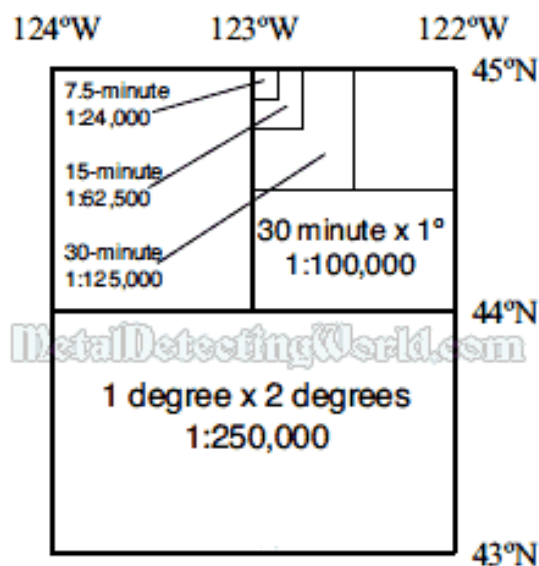
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Quadrangle names

A "quadrangle" is a topographic map produced by the United States Geological Survey (USGS) covering the United States. The maps are usually named after local physiographic features. The shorthand "quad" is also used, especially with the name of the map; for example, "the Ranger Creek, Texas quad". From approximately 1947-1992, the USGS produced the 7.5 minute series, with each map covering an area one-quarter of the older 15-minute quad series, which it replaced. A 7.5 minute quadrangle map covers an area of 49 to 70 square miles (130 to 180 km²). Both map series were produced via photogrammetric analysis of aerial photography using stereoplotters supplemented by field surveys.

On a quadrangle map, the north and south limits are not straight lines, but are actually curved to match Earth's lines of latitude on the standard projection. The east and west limits are usually not parallel as they match Earth's lines of longitude.



The USGS topographic quadrangles come in a variety of scales from 1:500,000 to larger scales (i.e. 1:24,000 scale). Each scale may be an appropriate base map for a geologic map, but the scale of map base used should be appropriate to the detail provided in a geologic map.

Latitude

Latitude is the measurement of distance north or south of the Equator. It is measured with 180 imaginary lines that form circles around the Earth east-west, parallel to the Equator. These lines are known as parallels. A circle of latitude is an imaginary ring linking all points sharing a parallel.

The Equator is the line of 0 degrees latitude. Each parallel measures one degree north or south of the Equator, with 90 degrees north of the Equator and 90 degrees south of the Equator. The latitude of the North Pole is 90 degrees N, and the latitude of the South Pole is 90 degrees S.

Like the poles, some circles of latitude are named. The Tropic of Cancer, for instance, is 23 degrees 26 minutes 21 seconds N—23° 26' 21" N. Its twin, the Tropic of Capricorn, is 23° 26' 21" S. The tropics are important geographic locations that mark the northernmost and southernmost latitudes where the sun can be seen directly overhead during a solstice.

One degree of latitude, called an arcdegree, covers about 111 kilometers (69 miles). Because of the Earth's curvature, the farther the circles are from the Equator, the smaller they are. At the North and South Poles, arcdegrees are simply points.

Degrees of latitude are divided into 60 minutes. To be even more precise, those minutes are divided into 60 seconds. One minute of latitude covers about 1.8 kilometers (1.1 miles) and one second of latitude covers about 32 meters (105 feet).

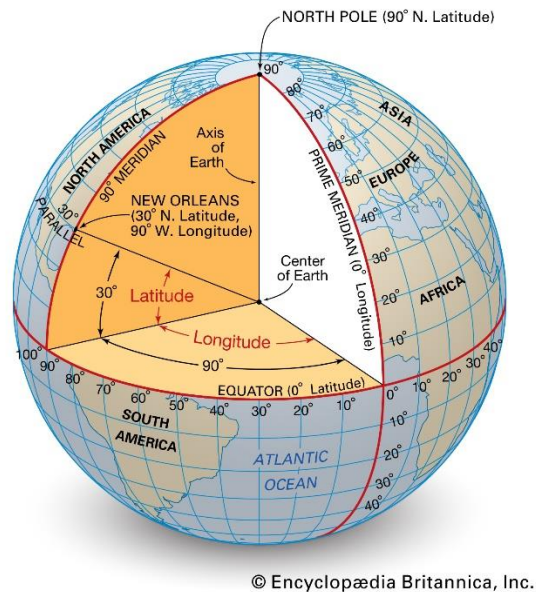
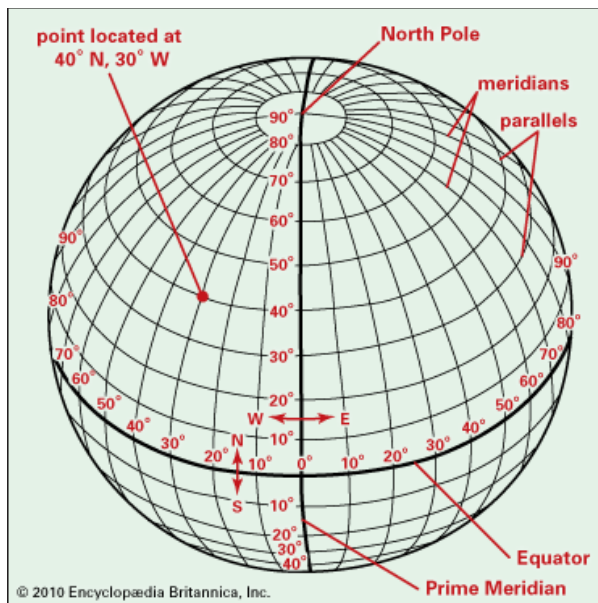
Longitude

Longitude is the measurement east or west of the prime meridian. Longitude is measured by imaginary lines that run around the Earth vertically (up and down) and meet at the North and South Poles. These lines are known as meridians. Each meridian measures one arcdegree of longitude. The distance around the Earth measures 360 degrees.

The meridian that runs through Greenwich, England, is internationally accepted as the line of 0 degrees longitude, or prime meridian. The antimeridian is halfway around the world, at 180 degrees. It is the basis for the International Date Line.

Half of the world, the Eastern Hemisphere, is measured in degrees east of the prime meridian. The other half, the Western Hemisphere, in degrees west of the prime meridian.

Degrees of longitude are divided into 60 minutes. Each minute of longitude can be further divided into 60 seconds. For example, the longitude of Paris, France, is 2° 29' E (2 degrees, 29 minutes east). The longitude for Brasilia, Brazil, is 47° 55' W (47 degrees, 55 minutes west).



UTM's

UTM is the acronym for Universal Transverse Mercator, a plane coordinate grid system named for the map projection on which it is based (Transverse Mercator). The UTM system consists of 60 zones, each 6-degrees of longitude in width. The zones are numbered 1-60, beginning at 180-degrees longitude and increasing to the east.

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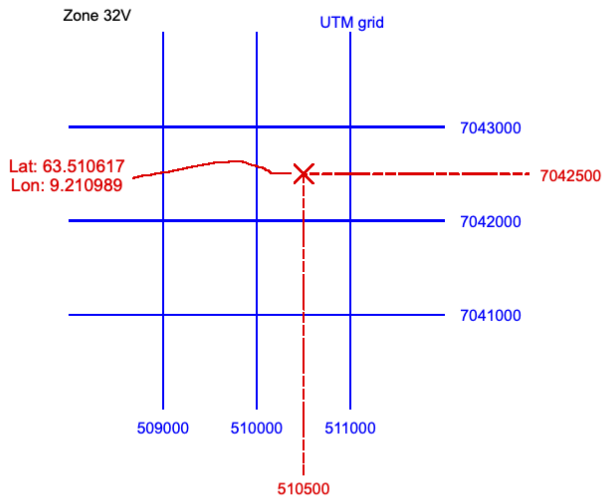
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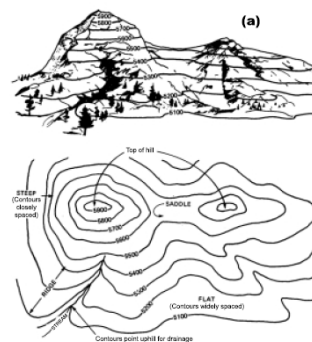
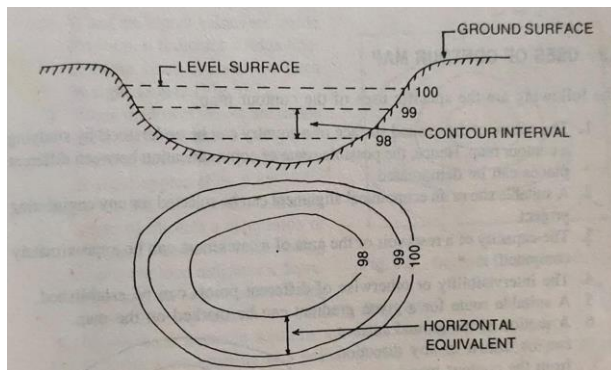
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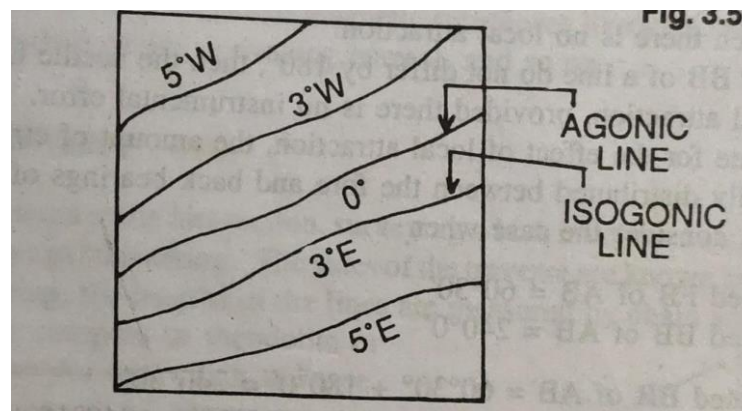
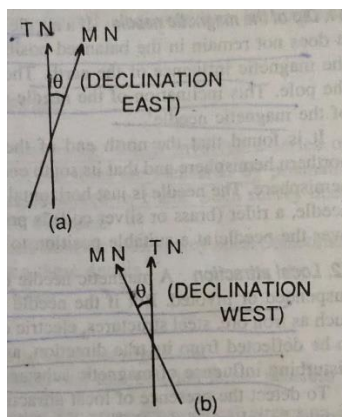
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