## 6.1 HORIZONTAL CURVES & LAY OUT

The horizontal alignment of a highway, railroad, or canal consists of series of straight lines and curves. The straight portions are called tangents. As shown in fig 2.17 successive tangents change direction by deflection angle designated Δ1. The change in direction of each intersection is distributed along a curve on series of curves in order to make a smooth transition. The curves in fig.2.17 are simple circular with radii designated R1 and central angle Δ1. Horizontal transition curves can also be made up of multiple circular curves of different radii called compound curves or of circular curves joined to the tangents by spirals of third degree.

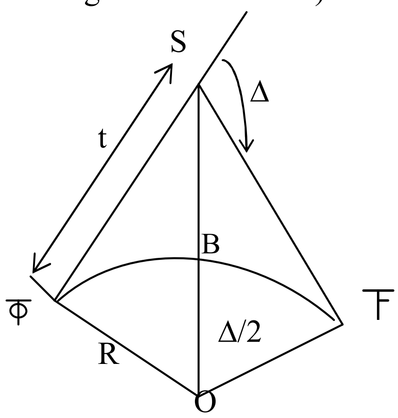
## 6.2 CIRCULAR CURVES

Included in the duties of an engineer in charge of constructional schemes is the setting out of works, an operation which is in some sense the reverse of surveying, in that measurements and other data are taken from the plan and transferred to the ground.

Where the works are completely defined straight lines, noting more need be said, as the setting-out operations are simple . the settings out, or ranging of curves, however, will be dealt with at some length as, in many types of construction curves will be required. For example, in road, railway or pipeline construction, two straights will normally be connected by a curve whenever there is a change in direction. The types of curves are the circular curve, the transition curve, and the vertical curve.

Two straights meet at the point of intersection S, and a circular arc is run between the straights, meeting than tangentially at the tangent points Φ and Ŧ

The radius of the curve is R, and the angle of deflection is as shown in figure given below (this angle is also sometimes referred to as the angle of deviation, or the angle of intersection)




Where ; Δ = deflection angle
R = radius of circle
O = center of curve
t = tangent distance
BS = bisected distance
Φ - Ŧ = Length of curve

Tangent length : $t = R * \tan \frac{\Delta}{2}$

Chord length : $D = \frac{2\pi R}{400}$

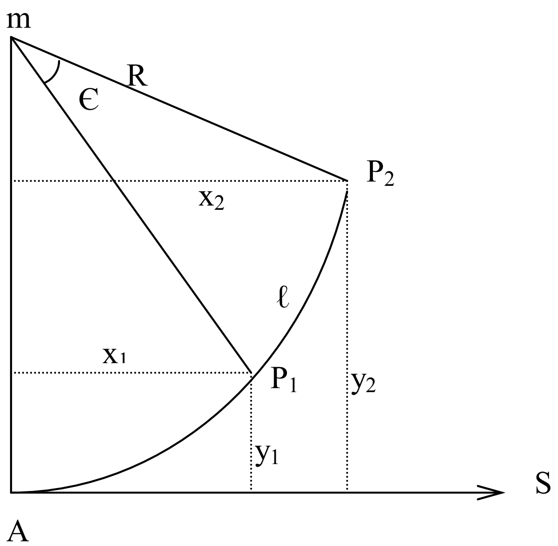
Bisected distance: $BS = R* \sec \frac{\Delta}{2} - R$

## 6.3 STAKING OF INTERMEDIATE POINTS

### 6.3.1 Rectangular Offsets From The Tangent

For this method, usually, either equal $\chi$ values or equal are lengths are used.

For stationing, usually equal are lengths $\ell$ are used. If the origin of the stationing coincides with the origin of the coordinate system, the following equations provide the x, y staking values:




$$Є = \frac{\ell}{R}$$

$x_1 = R \sin Є_1$

$x_2 = R \sin 2Є$

$x_3 = R \sin 3Є$

,

,

,

$x_n = R \sin nЄ$

$y_1 = R - R \cos Є$

$y_2 = 2R\, Sin^2 \frac{2\,Є}{2}$

$y_3 = 2R\, Sin^2 \frac{3\,Є}{2}$

,

,

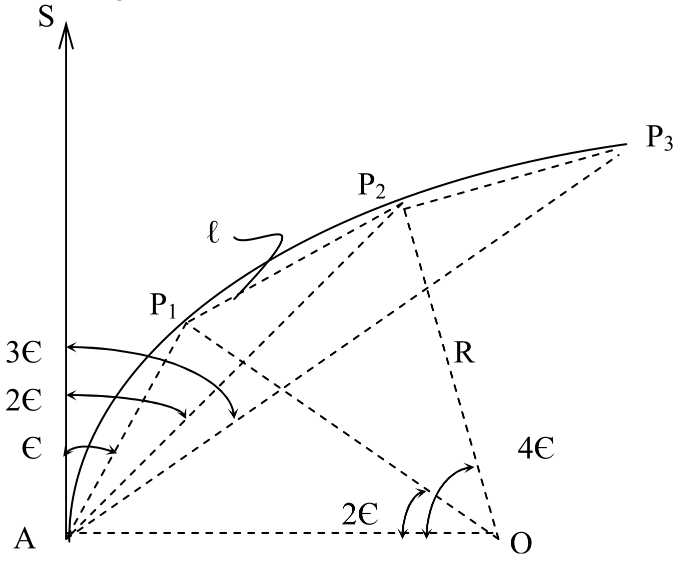
,

$y_n = 2R\, Sin^{2Φ} \frac{n3}{2}$

## POLAR STAKING

Polar staking methods have become increasingly popular, especially with the availability of electronic tachometers. A simple method can be derived using the starting point of the circle € is equal to the angle between the tangents and chord.

For equal arc lengths the polar staking elements are determined with respect to the tangent.




$$\sin \text{€} = \frac{\ell}{2R}; \quad \text{find} \rightarrow \text{€}$$

$AP_1 = 2R \sin\text{€}$

$AP_2 = 2R \sin 2\text{€}$

$AP_3 = 2R \sin 3\text{€}$

,

,

$AP_n = 2R \sin n\text{€}$

## CHAINAGE OF POINTS ALONG CURVE

For recording horizontal distances as well as for numbering the points along a route the so called station method is used. A station is established and numbered.
1- At every whole multiple of unit length (called full station) specified for that project.
2- At any other critical point defined by topography or geometry of route ($\overline{\Phi}$,S, $\top$). The station number which shows the horizontal distance to the points from the beginning of project will increase by one for every whole multiple of unit length and is called chainage of points. As the $\overline{\Phi}$ of a curve will rarely be at a full station. The distance from $\overline{\Phi}$ to the first full station on the curve will be, in general, less than the unit length. The central angle subtended by this distance is $\text{€}_1$. A similar situation will be found also at midpoint of the curve and at $\top$ as well. In practice after computing elements of the curve chainage of points are determined which is used to prepare lay out table.

Example:

Given chainage of S =125+15
unit length = 30m=1+00
tangent length(t) = 50m=1+20
length of curve = 90m=3+00

1. Chainage of main points of curve ( $\overline{\Phi}$,S, $\top$ ) Note that 125+15 means that there are 125 full (30m) station and one half (15m) station so 125+15=125*30+15= 3765m. horizontal distance from beginning of project S.

Chainage of S 125+15
-t = 50m = 1+20 -1+20
Chainage of Φ 123+25

+ curve lenght/2 1+15
45= 1+15 +
124+40 =125+10→ chainage of B

+curve lenght/2 1+15
45= 1+15 +
126+25 → chainage of ⊤

check Φ - ⊤ = curve lenght -123+25
3+0 O.K. checks

2. chain of full stations

| Point | Chainage | Distance | Target Point |
|---|---|---|---|
| Φ | 123+25 | | |
| 1 | 124+00 | 5m | Full Station |
| 2 | 125+00 | 30m | Full Station |
| B | 125+10 | 10m | Mid Point |
| 3 | 126+00 | 20m | Full Station |
| ⊤ | 126+25 | 25m | |

$\sum$= 90m O.K. Check Lenght of Curve

**CURVE SELECTION & LAY OUT METHODS**

The selection of curve will be dictated by field conditions and standard of the route. On highways a maximum degree of curve (minimum radius) is specified to provide safe and comfortable driving. The unit chord or arc length is determined according to this maximum degree of curve.

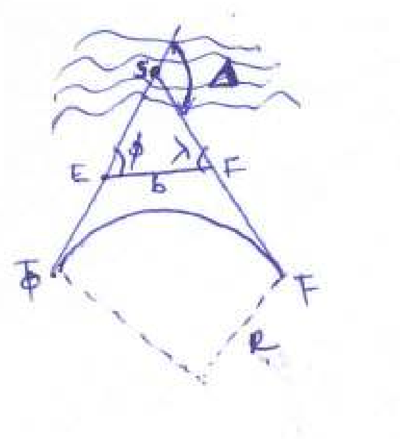
Curve ranging or layout aims to establish the arc from Φ to ⊤ by staking full stations as well as main curve points. The selection of the lay out method will be dictated by

- Accuracy requirement of project
- Degree of the curve
- Topography and field conditions
- Instrumentation available

  Staking out by deflection angles and chords is the standard method . theodolite is set up at Φ and referenced to S with zero reading. The deflection angles are measured to points on the arc and unit length chord distances are measured to from Φ and from previous points set up in similar manner. The deflection angles and corresponding chord lengths for each point are computed before going to the field.

## POSSIBLE DIFFUCULTIES IN SETTING OUT SIMPLE CURVES

**a)** If S is inaccessible, an auxiliary line EF is staked. After measuring $\phi$ ,$\lambda$ b; ES and FS are computed in triangle EFS.




$\Delta = \phi + \lambda$

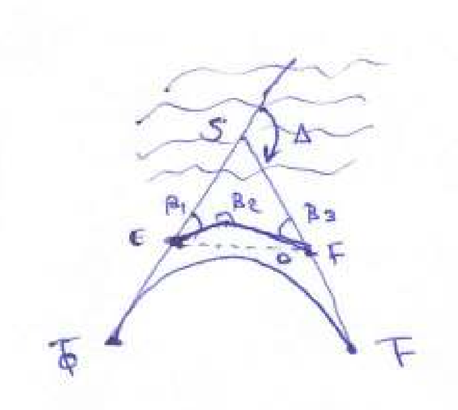
$$\frac{\overline{SE}}{\sin\chi} = \frac{\overline{SF}}{\sin\phi} = \frac{\overline{EF}=b}{\sin(\phi+\lambda)}$$

$$\overline{SE} = b\,\frac{\sin\lambda}{\sin(\phi+\lambda)} \quad ; \quad SF = b\,\frac{\sin\phi}{\sin(\phi+\lambda)}$$

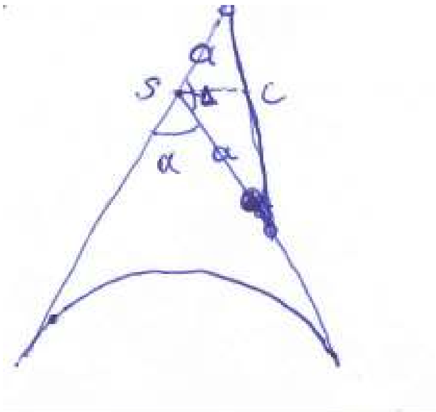
$t = SE + E\overline{\Phi} = SF + F\overline{F}$

$E\overline{\Phi} = t - SE$ ; $F\overline{F} = t - SF$

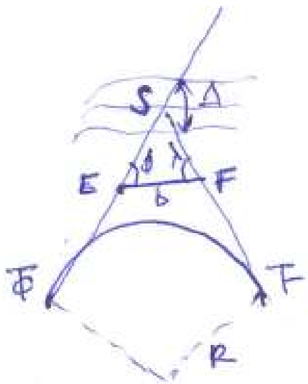
**b)** If b , $\phi$, $\lambda$ can not be measured, E and F have to connected by a traverse or a triangular system.



c) If a theodolite is not available for measuring deflection angle ( let say $\alpha$) , then equal section $\alpha$ are staked along the tangents from S. After measuring the distance C between this points, the angle $\alpha$ is obtained as $\sin\Delta = c/2a$




**EXAMPLE 1**




S is inaccasible , an auxilary line EF is staked

$\phi = 60^{g}$

$\lambda = 75^{g}$

b= 80m

Compmte the elements of curve if R=200m

$\Delta = \phi + \lambda = 60 + 75 = 135^{g}$

$$\overline{SE} = 80 \frac{\sin 75}{\sin(60+75)} = 86{,}68m$$

$$\overline{SF} = 80 \frac{\sin 60}{\sin(60+75)} = 75{,}91m$$

t = 200* sin 67,5$^{g}$ = 174,50m

E$\overline{\Phi}$ = 174,50-86,68 = 87,82m

F$\overline{T}$ = 174,50-75,91 = 98,59m

**EXAMPLE 2:**Chainage of S is 207.70m and lenght of curve is 78,20m. Straking of intermediate points will be realized by rectangular offset from the tangent and arc lenghts are equal to 10m. radius of curve is 200m. compute the elements of curve.

$$\epsilon_1 = \frac{210-204,70}{200} * 63,66 = 1,69^{g}$$

$$\epsilon = \frac{220-10}{200} * 63,66 = 3,18^{g}$$

$\chi_1 =$ Rsin 1,69=5,31
$\chi_2 =$ Rsin (3,18+1,69)=15,28
$\chi_3 =$ Rsin (3,18+3,18+1,69)=28,01

$$\gamma_1 = 2R \sin^2\frac{169}{2} = 0,07$$

$$\gamma_2 = 2R \sin^2\frac{(3,18+1,69)}{2} = 0,72$$

$$\gamma_3 = 2R \sin^2\frac{(3,18+3,18+1,69)}{2} = 1,60$$

**EXAMPLE 3 :** Chairage of Φ is 3505,20 and Τ is 3638,40m. Radius of curve is 200m. If the unit lenght of curve is 20m,compute staking out elements of curve using by polar method.

3520-3505,20=14,80

$$\epsilon_1 = \frac{14.80}{200} 63,6620 = 4,7110^{g}$$

3638,40-3620=18,40

$$\epsilon_n = \frac{18,40}{200} 63,6620 = 5,8569^{g}$$

For each 20m are lenght

$$\epsilon = \frac{20}{200} 63,6620 = 6,3662^{g}$$

$\epsilon 1 = 2,3555^g$

$\epsilon 2 = 2,3555 + 3,1831 = 5,5386^g$

$\epsilon 3 = 5,5386 + 3,1831 = 8,7217$

$\epsilon 4 = 8,7217 + 3,1831 = 11,9048$

$\epsilon 5 = 11,9048 + 3,1831 = 15,0879$

$\epsilon 6 = 15,0879 + 3,1831 = 18,2701$

$\epsilon_{F} = 18,2710 + 2,9284 = 21,1944$

$\Phi P_1 = 14,80$

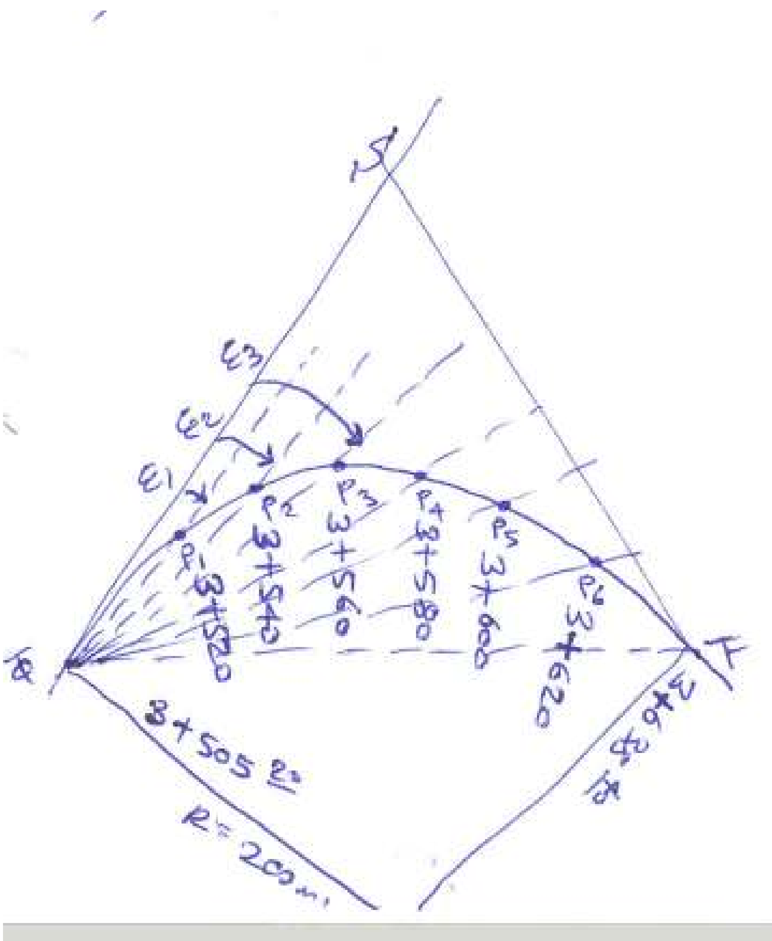
$\Phi P_2 = 34,76$

$\Phi P_3 = 54,63$

$\Phi P_4 = 74,36$

$\Phi P_5 = 93,92$

$\Phi P_6 = 113,23$



**10.** Two points at a slope distance 1.00m apart have difference in elevation of 12.00 m. What slope distance should be measured in order to lay out a horizontal distance of 1000.00 m. if the 30m tape used in 12 mm longer than the standard length?

**11.** In taping down a hill with a 30m steel type the head tapeman held each time his end (30m) of the tape 1.00 m lower than horizontal position ( in order to tape longer distance each time). A distance of 510.000 m was measured this way. Compute the true horizontal distance between the two points.

**12.** If S = slope distance, D = horizontal distance, h= elevation difference, g =% slope,α= vertical angle, n in m, n vertical m horizontal;

**a)** S = 200m, α = -3.125 convert to h,g,2 in m
**b)** D = 300m, g = 6.52% convert to h,α,n in 15
**c)** D = 150m, h = -3.14m convert to α,g,1 in m
**d)** g = -5.5%, h = 12.65m convert to D,S, α, n in 10

**13.** To what accuracy must the slope angle in Problem 1 be measured if the relative accuracy of the horizontal distance is to be 1:25,000?

**14.** To what accuracy must the slope angle in Problem 1 be measured if the horizontal distance is to be accurate to ± 2 mm ?

**15.** A building 80m by 160m is to be laid out by using a 20m steel tape. The 20 m steel type was brought to survey lab and the standard distance (of 20.000m) is measured as 19.994m. What ground measurements should be made in the field in order to lay out the two sides of the building? After laying out the corners of the building, one diagonal is measured for checking . What should be the measured value for the diagonal?

**16.** With what accuracy the difference in elevation between the two ends of a 30 m tape be known if the difference in elevation is 2.880m and the accuracy ratio is to be better than 1:25,000?

**17.** What error in a measured distance results from the conditions noted below?
**a)** One end of a 30m tape is off-line by 1.00m
**b)** One end of a 50m tape is too high by 0.50m
**c)** One end of a 20m tape is off-line by 0.30m & too low by 0.50m