

# Module-6

## Introduction to Curve

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# Content:

- Module-6 Syllabus
- Introduction and Definition
- Types of Curves
- Terminologies associate with Curve
- Degree of the Curve
- Setting out of Curves

## **MODULE-6**

Curves, types of curves, simple circular curves, compound curves, reverse curves, transition curves and vertical curve, setting out of curves.

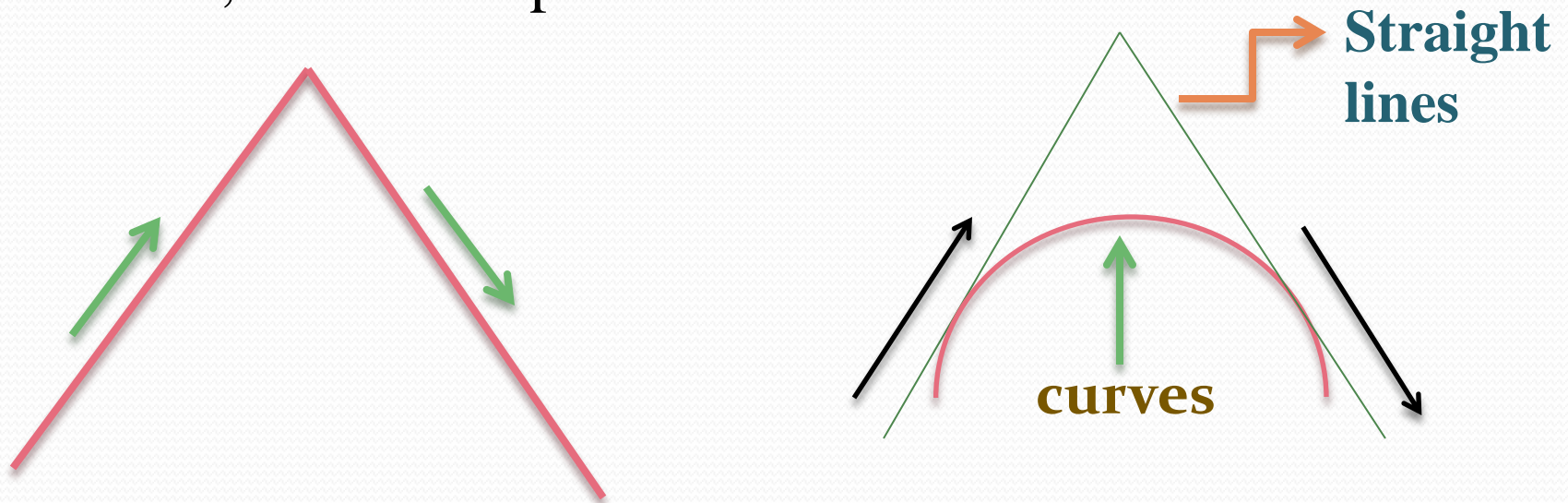
Practice:

1. Setting out of the curve off set from long chord method using total station
2. Setting out of the curve by chord produced method using total station
3. Setting out of compound curve
4. Setting out of reverse curve

# Introduction:-

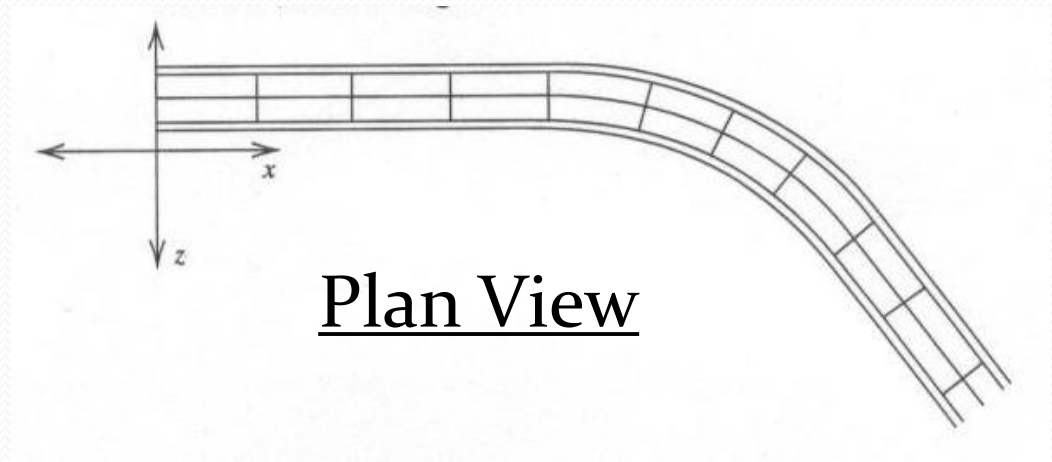
- Curves are provided whenever a road changes its direction from right to S (vice versa) or changes its alignment from up to down (vice versa).
- Curves are a critical element in the pavement design. They are provided with a maximum speed limit that should be followed very strictly.
- Following the speed limit becomes essential as the exceed in speed may lead to the chances of the vehicle becoming out of control while negotiating a turn and thus increase the odds of fatal accidents.

- Also, it is very necessary that appropriate safety measures be adopted at all horizontal and vertical curves to make the infrastructure road user friendly and decrease the risks of hazardous circumstances.
- The low cost safety measures that can be adopted at curves included chevron signs, delineators, pavement markings, flexible posts, fluorescent strips, road safety barriers, rumble strips etc.



# Components of Highway Design

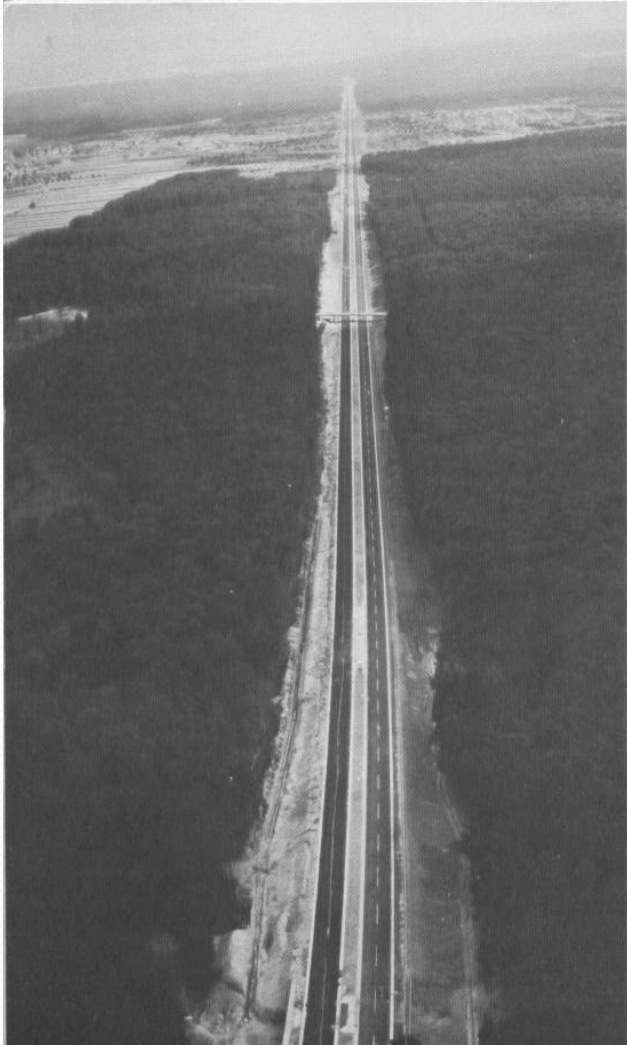
## Horizontal Alignment



## Vertical Alignment



# Horizontal Alignment



Tangents



Curves





# Curves

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graph TD; Curves[Curves] --> Horizontal[Horizontal Curves]; Curves --> Vertical[Vertical Curves]; Horizontal --> Circular[Circular Curves]; Horizontal --> Transition[Transition Curves]; Circular --> C1[1. Simple Curve]; Circular --> C2[2. Compound Curve]; Circular --> C3[3. Reverse Curve]; Transition --> T1[1. Cubic Parabola]; Transition --> T2[2. Spiral curve]; Transition --> T3[3. Lemniscates]; Vertical --> V1[1. Summit Curve]; Vertical --> V2[2. Valley Curve];
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## Horizontal Curves

## Vertical Curves

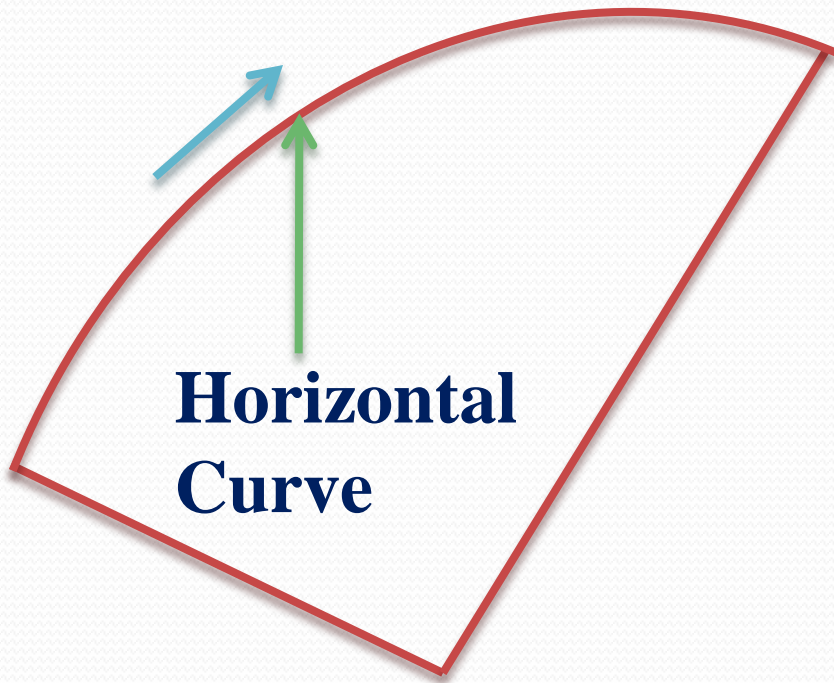
### Circular Curves

### Transition Curves

1. Simple Curve
2. Compound Curve
3. Reverse Curve

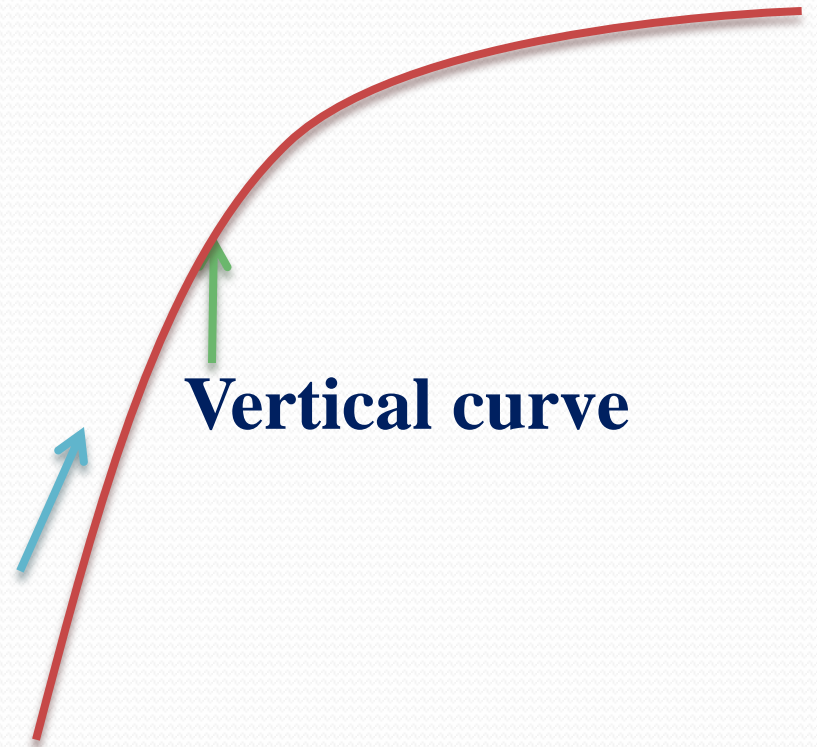
1. Cubic Parabola
2. Spiral curve
3. Lemniscates

1. Summit Curve
2. Valley Curve



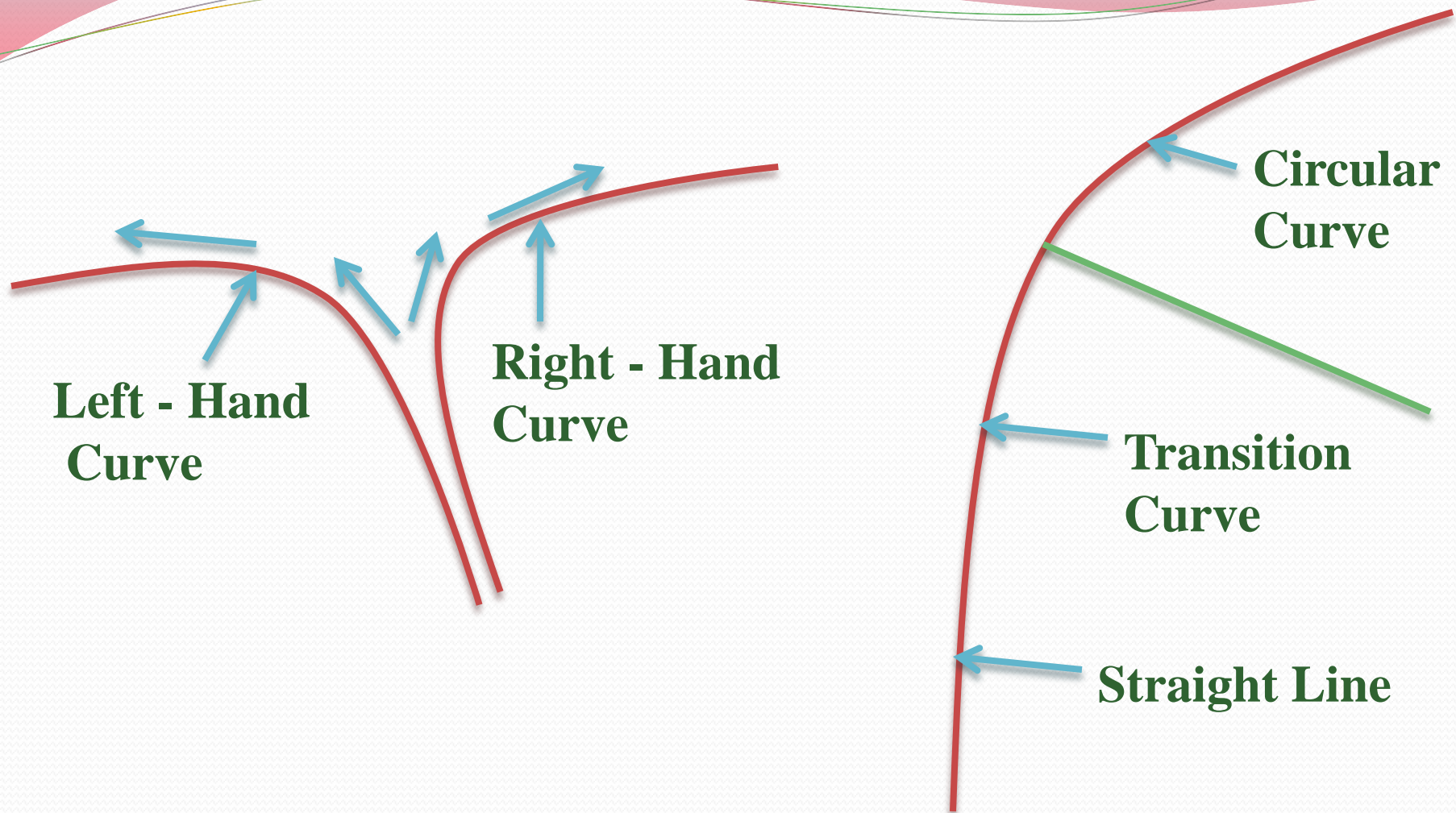
**Horizontal  
Curve**

**(i) Plan**



**Vertical curve**

**(ii) Elevation**

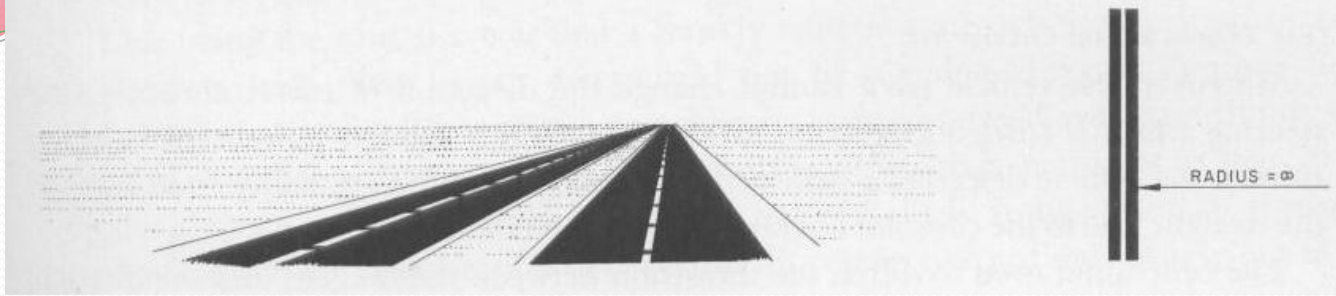


# Classification Of Curves

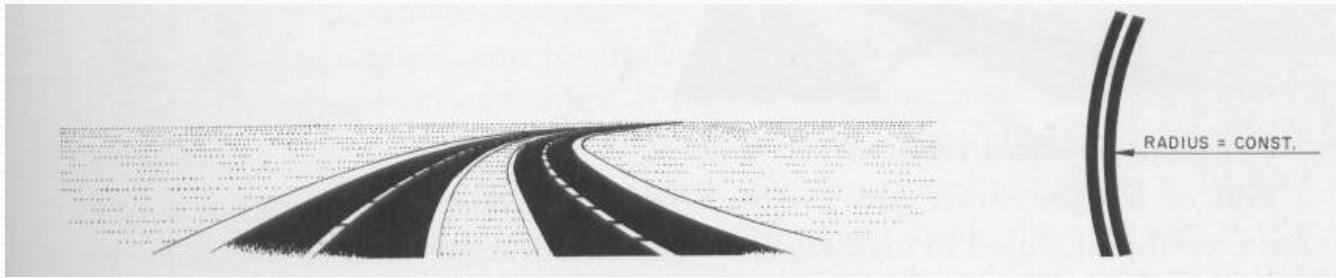
# Horizontal Curves:

- Horizontal curves are in plan, while vertical curves in a vertical section.
- Horizontal curves are provided to change the direction or alignment of a road.
- Horizontal Curve are circular curves or circular arcs.
- The sharpness of a curve increases as the radius is decrease which makes it risky and dangerous.
- The main design criterion of a horizontal curve is the provision of an adequate safe stopping sight distance.

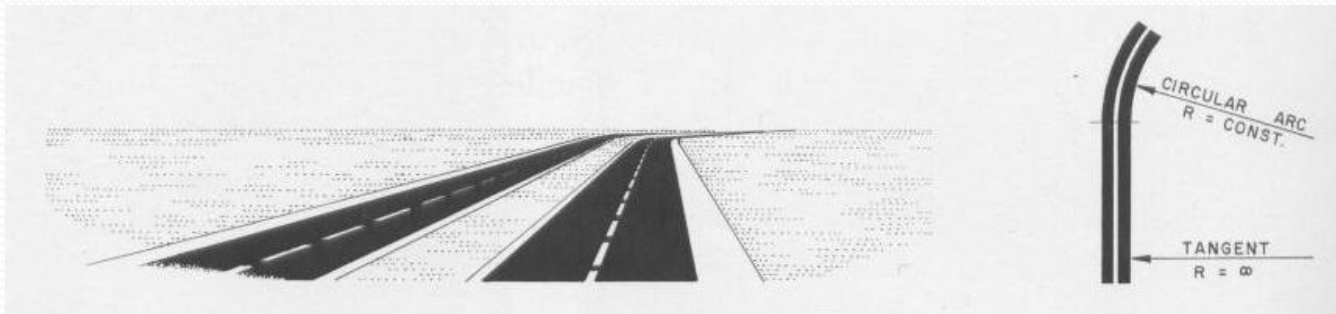
# Tangents & Curves



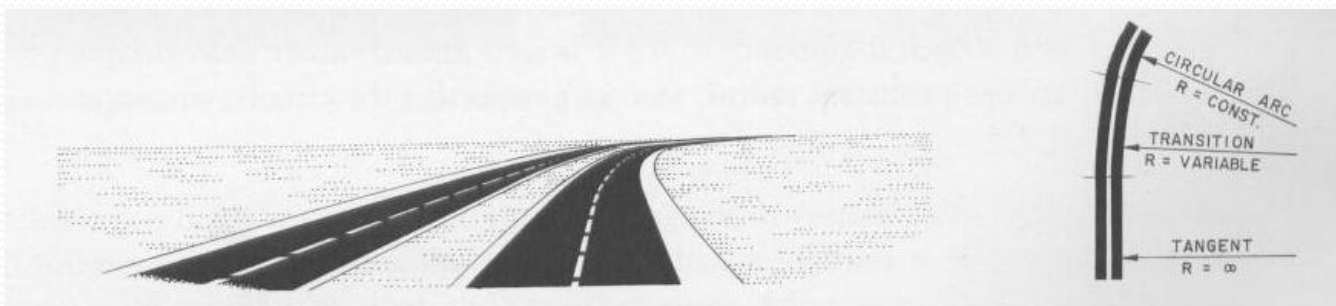
Tangent



Curve



Tangent to  
Circular Curve



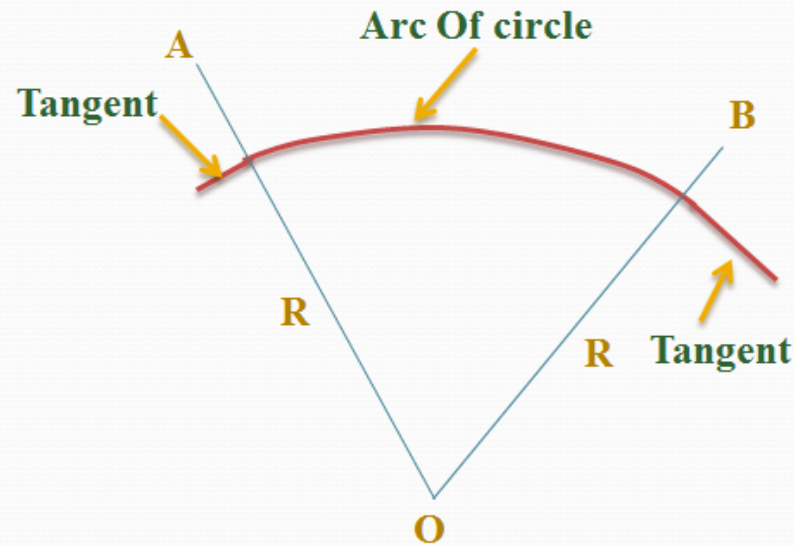
Tangent to  
Spiral Curve to  
Circular Curve

# Types Of Circular Curves

- There are three types of circular curves:
  1. Simple curve
  2. Compound curve
  3. Reverse curve

# 1) Simple curve:

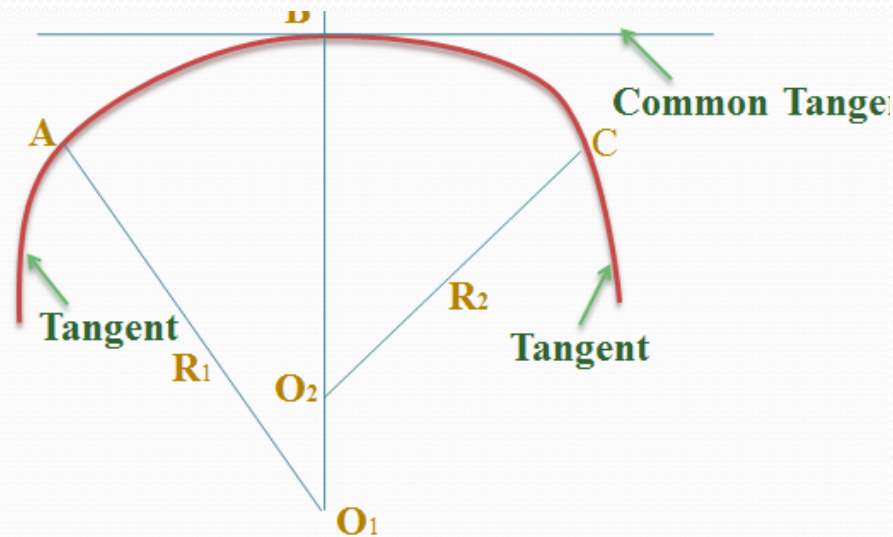
- A simple curve consists of a single arc of the circle.
- It is tangential to both the straight lines.
- A simple arc provided in the road to impose a curve between the two straight lines.



**Simple Curve**

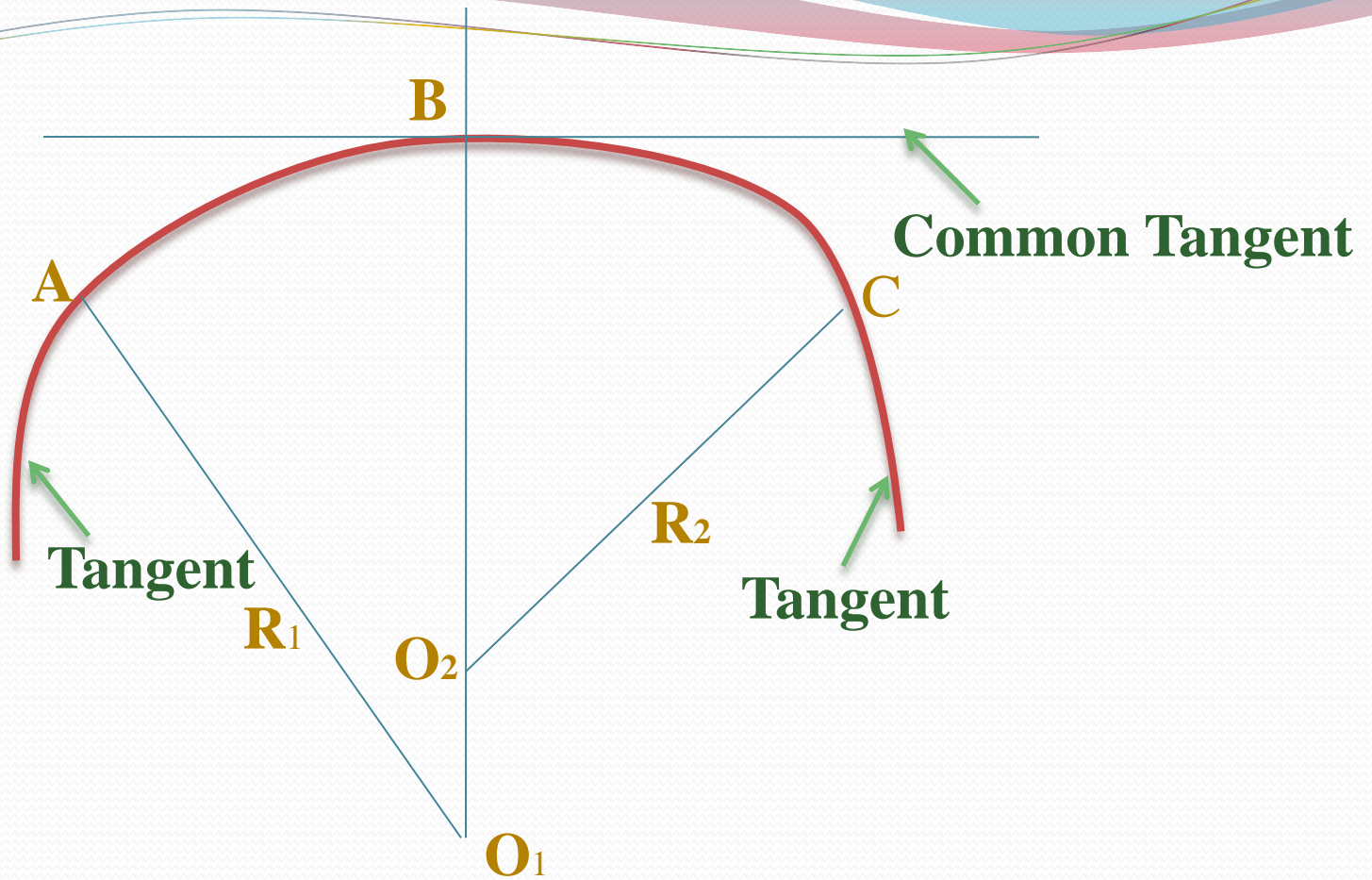
## 2) Compound Curves:

- A compound curve consists of two or more simple arcs.
- Combination of two simple curves combined together to curve in the same direction
- The simple arcs turn in the same direction with their centers of curvature on the same side of the common tangent.



**Compound Curve**

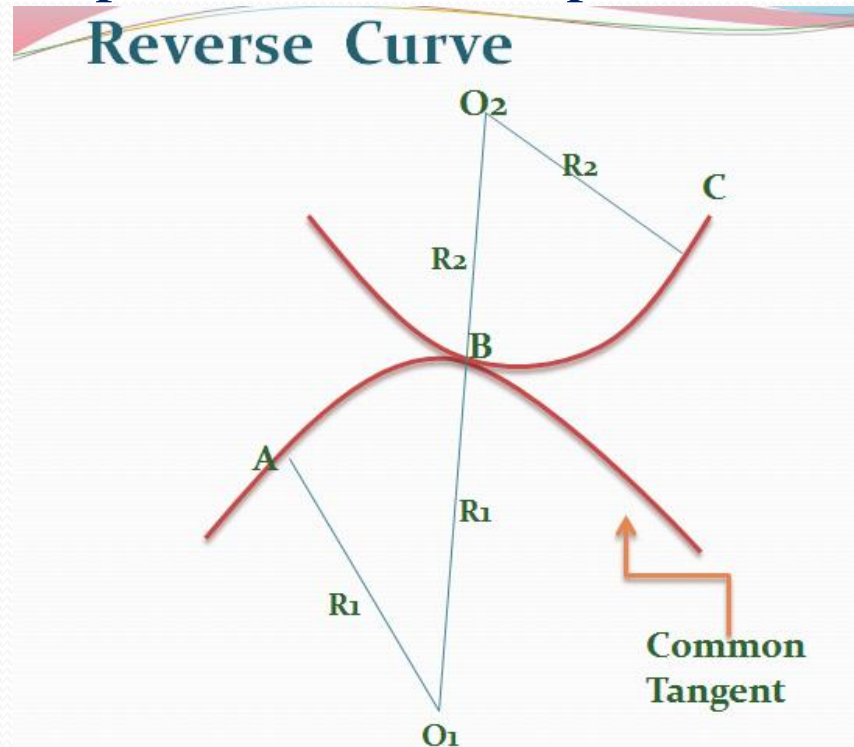




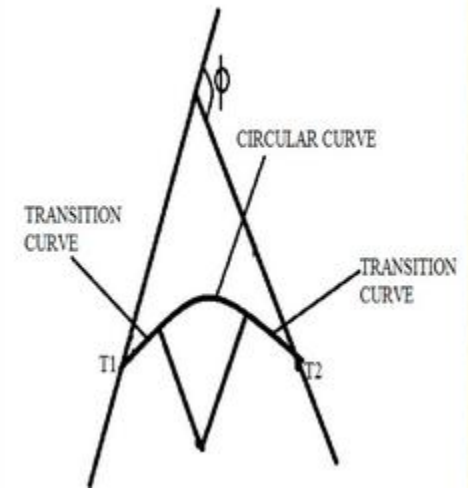
# Compound Curve

### 3) Reverse Curve :

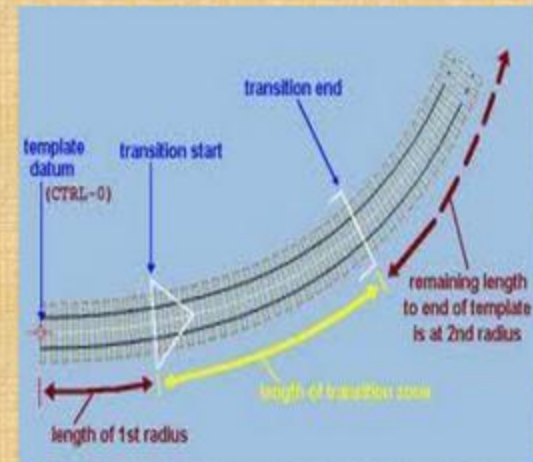
- A reverse curve consists of two circular arcs which have their centers of curvature on the opposite side of the common tangent.
- The two arcs turn in the opposite direction .
- Reverse curves are provided for low speed roads and railways.



- **A transition curve** may be defined as a curve of varying radius of infinity at tangent point to a design circular curve radius provided in between the straight and circular path in order that the centrifugal force was gradual. This is also known as easement curve.



1. Must attain specified cant at junction
2. Rate of change of cant must equal that of the curve
3. Radius of transition curve at junction should be equal to radius of circular curve
4. Must meet the circular curve tangentially



- The objectives of providing transition curve are given below:
  - To gradually introduce the centrifugal force between the tangent point and the beginning of the circular curve thereby avoiding sudden jerk on the vehicle.
  - To increase the comfort of passengers.
  - To introduce designed superelevation at a desirable rate
  - To enable the driver to turn the steering gradually for his own comfort and security
  - To introduce designed extra widening at a desirable rate
  - To enhance the aesthetic appearance of the road
  - To fit the road alignment in a given alignment
  - To minimize the effects of centrifugal force, the speed of the vehicle should be gradually reduced or a path should be negotiated with the gradual change of trajectory so that the radius of curvature is gradually reduced from infinity to  $R$  or to get the combined effect of both.

# CONCEPT OF SUPERELEVATION

“The height through which the outer edge of the road or rail is raised to counterbalance the centrifugal force is called **Superelevation** or **Cant**.”

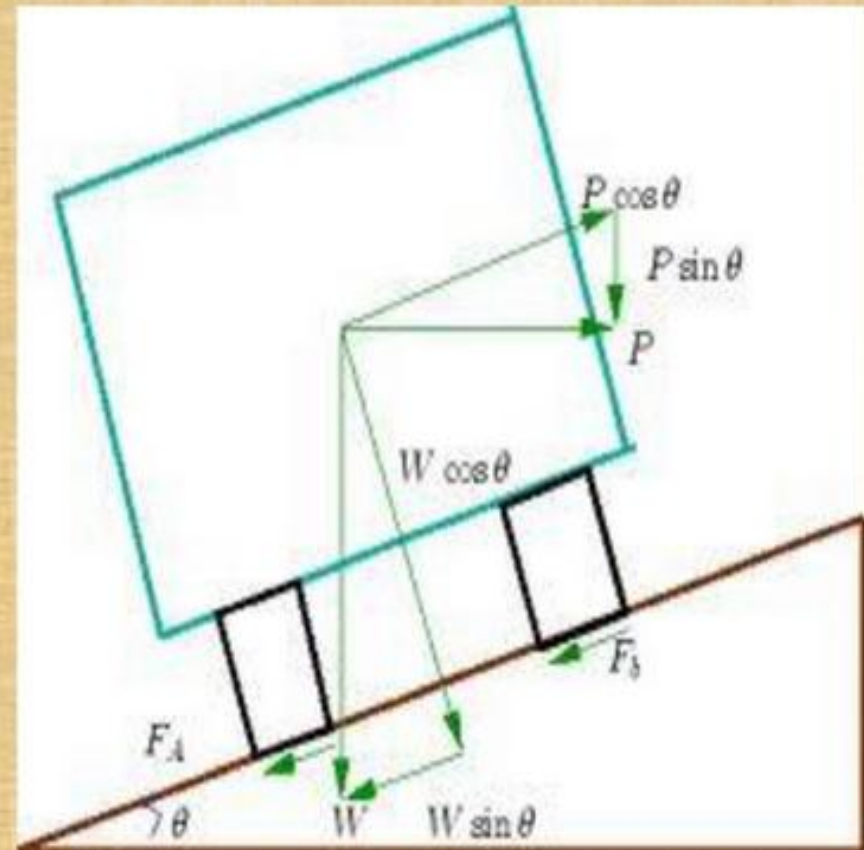
## Equation of Superelevation:

### 1. For road:

$$\text{Superelevation} = (Bv^2 / gR)$$

### 2. For rail:

$$\text{Superelevation} = ( Gv^2 / gR)$$

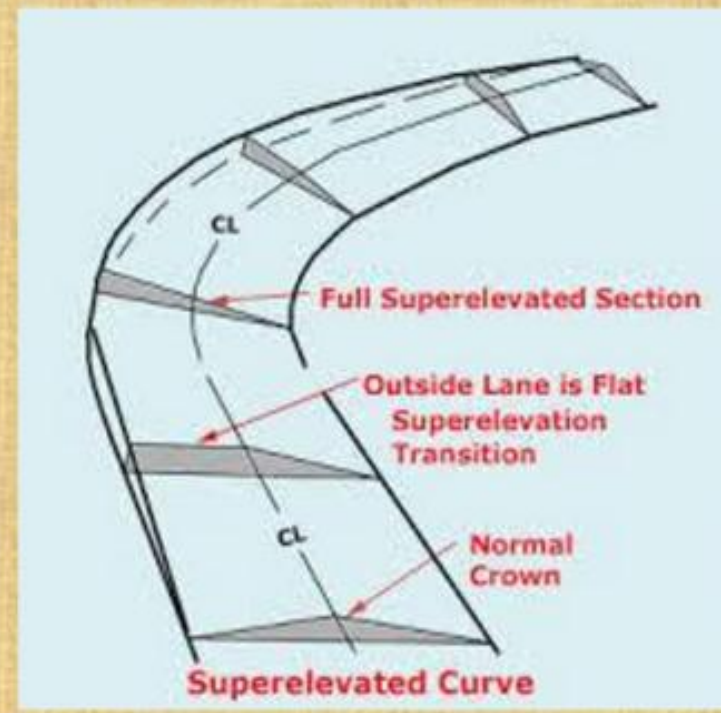


# CENTRIFUGAL RATIO

“**Centrifugal ratio** is defined as the ratio of the centrifugal force to the weight of the vehicle.”

$$\text{C.R.} = P/W = [Wv^2 / (gRW)] = v^2 / (gR)$$

1. Allowable value of C.R. for road = **0.25**
2. Allowable value of C.R. for rail = **0.125**



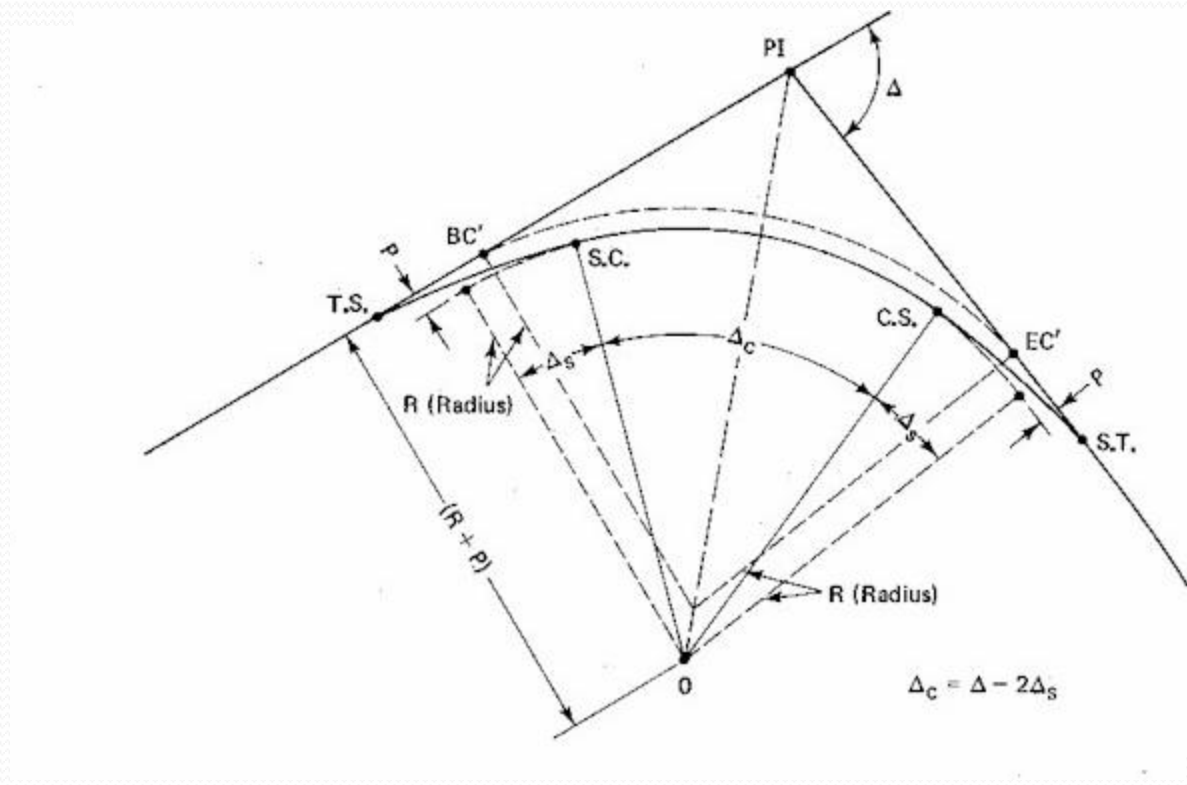
# USE OF TRANSITION CURVE

1. Superelevation
2. Maintenance of constant proportionality of superelevation
3. Prevention of overturning of vehicles
4. Reduce wear and tear of rail section



# Spiral Curve

A transition curve is sometimes used in horizontal alignment design. It is used to provide a gradual transition between tangent sections and circular curve sections. Different types of transition curve may be used but the most common is the **Euler Spiral**.



Properties of Euler Spiral

(reference: **Surveying: Principles and Applications**, Kavanagh and Bird, Prentice Hall]



# Definations and Notations for simple curve :

- **Back tangent :**

The tangent (AT1) previous to the curve is called the back tangent or first tangent .

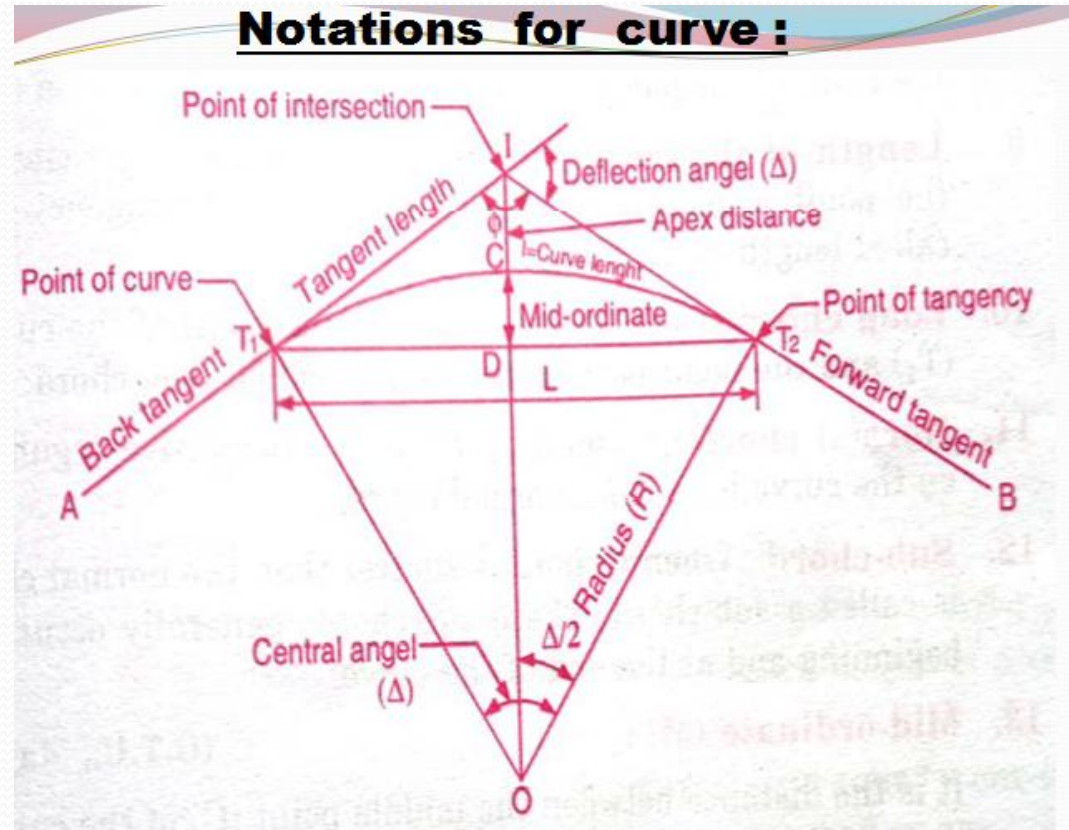
- **Forward tangent :**

The tangent (T2B) following the curve is called the forward tangent or second tangent .

- **Point of Intersection (P.I.) :**

If the tangent AT1 and BT1 are produced they will meet in a point , called the point of intersection . It is also called vertex (V).

## Notations for curve :



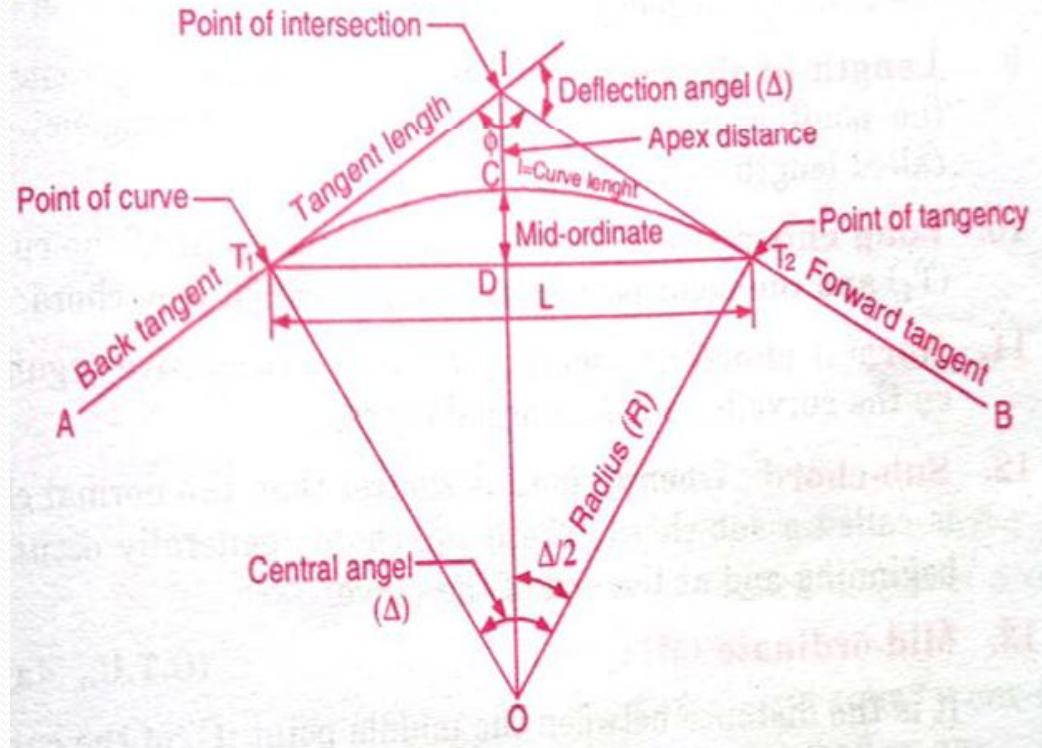
- **Point of curve (P.C.)**

:It is the beginning point  $T_1$  of a curve . At this point the alignment changes from a tangent to a curve .

- **Point of tangency (P.T.) :**

The end point of a curve ( $T_2$ ) is called the point of tangency .

### Notations for curve :



- **Intersection angle ( $\phi$ ) :**

The angle AVB between tangent AV and tangent VB is called intersection angle .

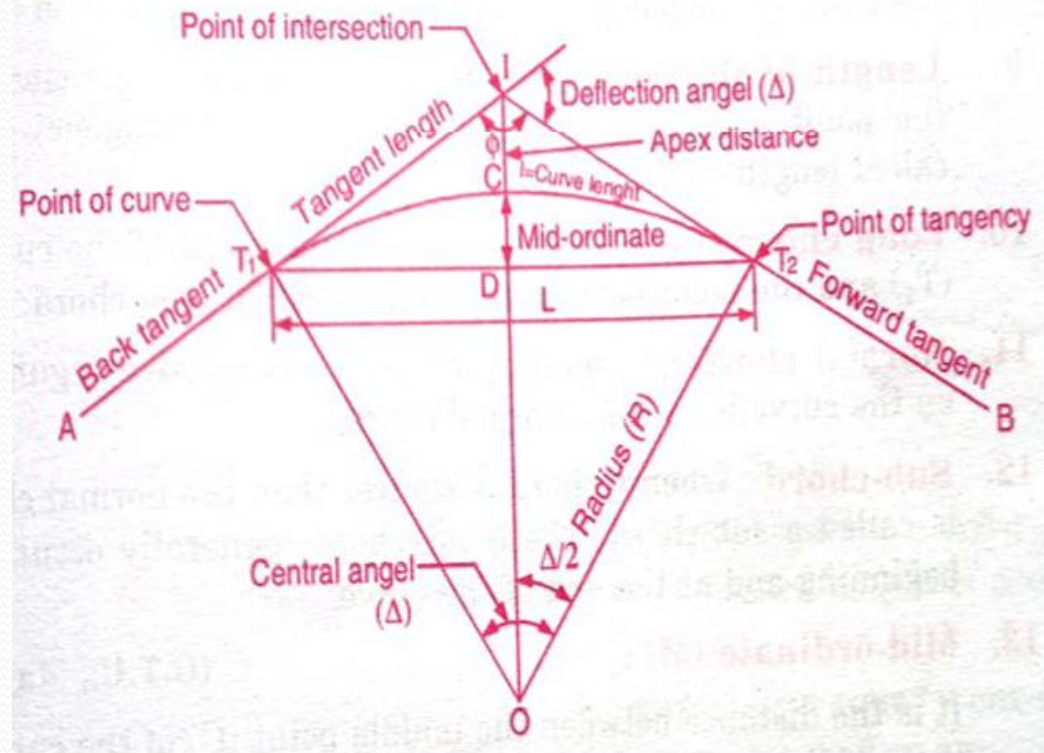
- **Deflection angle ( $\Delta$ ) :**

The angle at P.I. between the tangent AV produced and VB is called the deflection angle .

- **Tangent distance :**

It is the distance between P.C. to P.I. It is also the distance between P.I. and P.T.

### **Notations for curve :**



- **External distance (E) :**

It is the distance from the mid point of the curve to P.I. It is also called the apex distance.

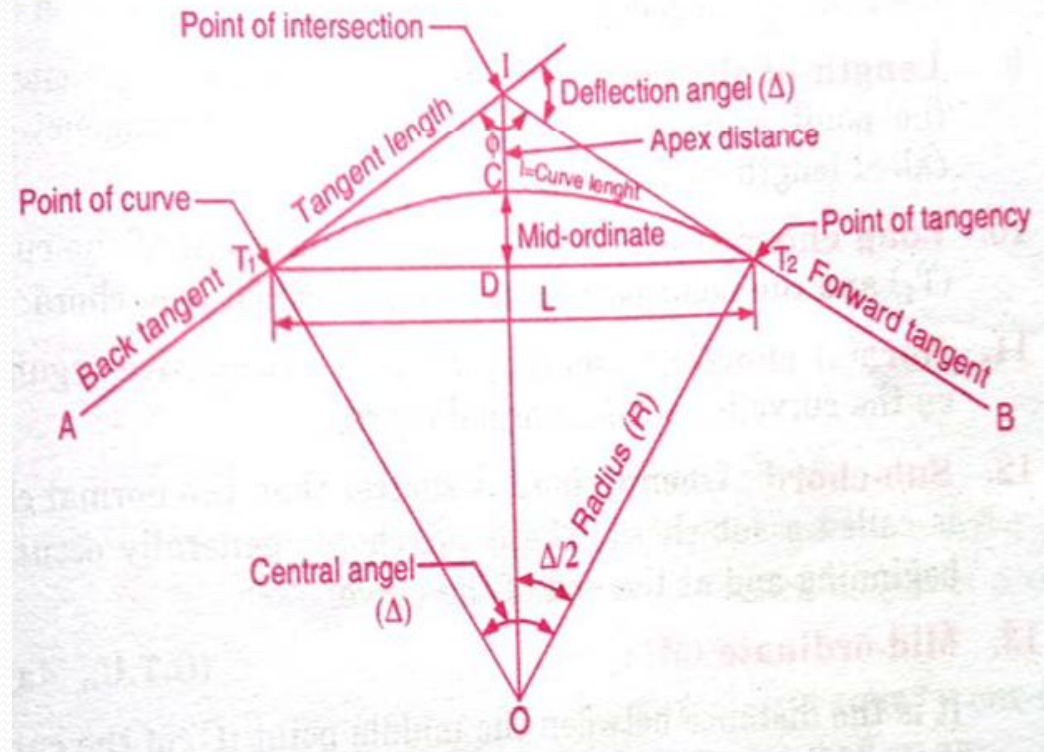
- **Length of curve (l) :**

It is the total length of curve from P.C. to P.T.

- **Long chord :**

It is chord joining P.C. to P.T.  $T_1T_2$  is a long chord .

### **Notations for curve :**



# Element of simple circular curve :

- 1) Length of curve ( l )
- \* If curve is designated by Radius:

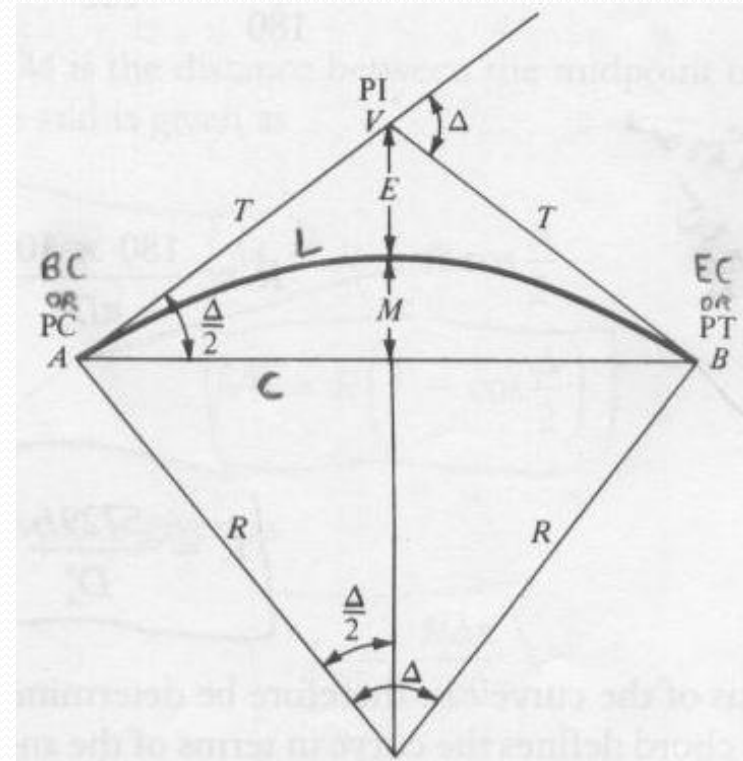
l = Length of arc T<sub>1</sub> C T<sub>2</sub>  
 = R \* Δ - When Δ is in Radian

$$l = \frac{R \Delta \pi}{180} \text{ - When } \Delta \text{ is in degree.}$$

- \* If curve is designated by degree:

- Length of arc = 20 mt
- Length of curve

$$l = \frac{20 \Delta}{D} \text{ mt.}$$





# Element of simple circular curve :

## 3) Length of chord ( L ): Elements of simple circular curve

- In the figure  $T_1, T_2$  is a long chord.
- Length of long chord =  $L = T_1T_2 = 2 * (T_1 D)$ .
- From triangle  $T_1DO$ ,

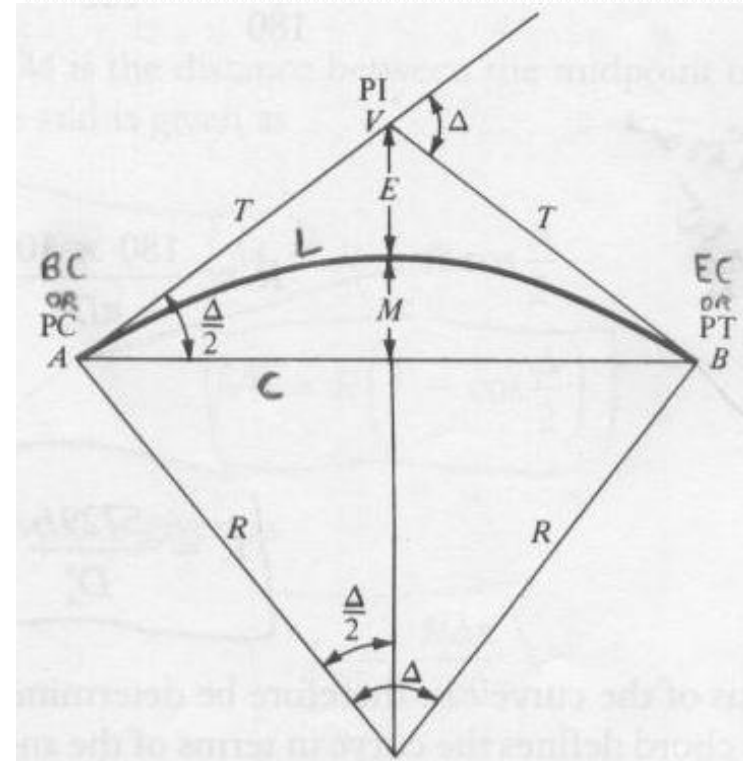
$$\sin \frac{\Delta}{2} = \frac{T_1 D}{T_1 O} = \frac{T_1 D}{R}$$

$$\therefore T_1 D = R \sin \frac{\Delta}{2}$$

$$\therefore L = 2T_1 D$$

$$\therefore L = 2R \sin \frac{\Delta}{2}$$

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# Element of simple circular curve :

- **5) Mid ordinate ( M ) := Distance – CD**
- Also known as versed sine of the curve.
- Mid ordinate = M = CD = OC - OD

- From  $\Delta T_1DO$

$$\cos \frac{\Delta}{2} = \frac{OD}{OT_1} = \frac{OD}{R}$$

$$\therefore OD = R \cos \frac{\Delta}{2}$$

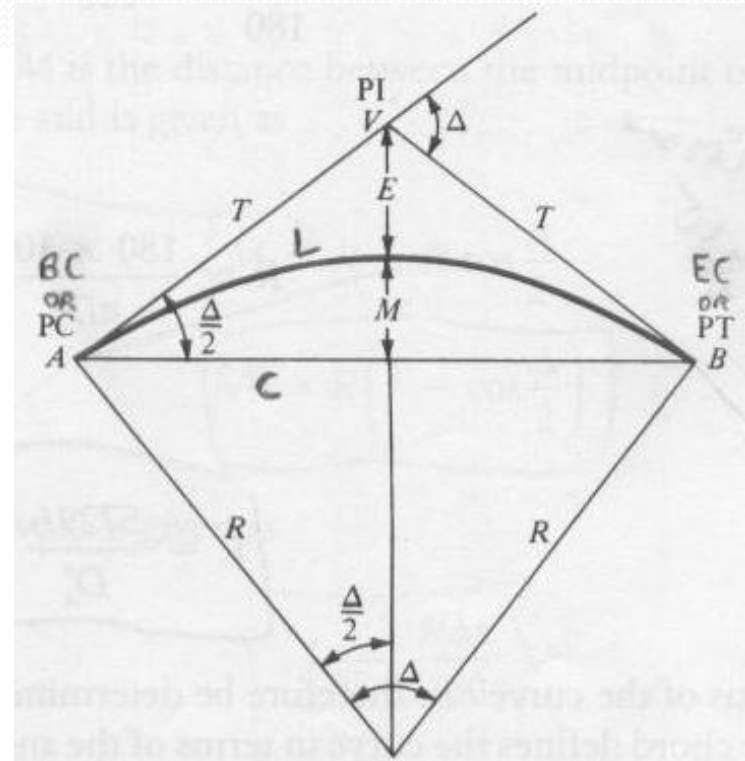
$$M = OC - OD$$

$$= R - R \cos \frac{\Delta}{2}$$

$$\because OC = R$$

$$\therefore M = R \left[ 1 - \cos \frac{\Delta}{2} \right]$$

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- **Normal chord :**

A chord between two successive regular stations on a curve is called **normal chord** . Normally , the length of normal chord is chain (20 m).

- **Sub chord :**

The chord shorter than normal chord (shorter than 20m) is called **sub chord** .

- **Versed chord :**

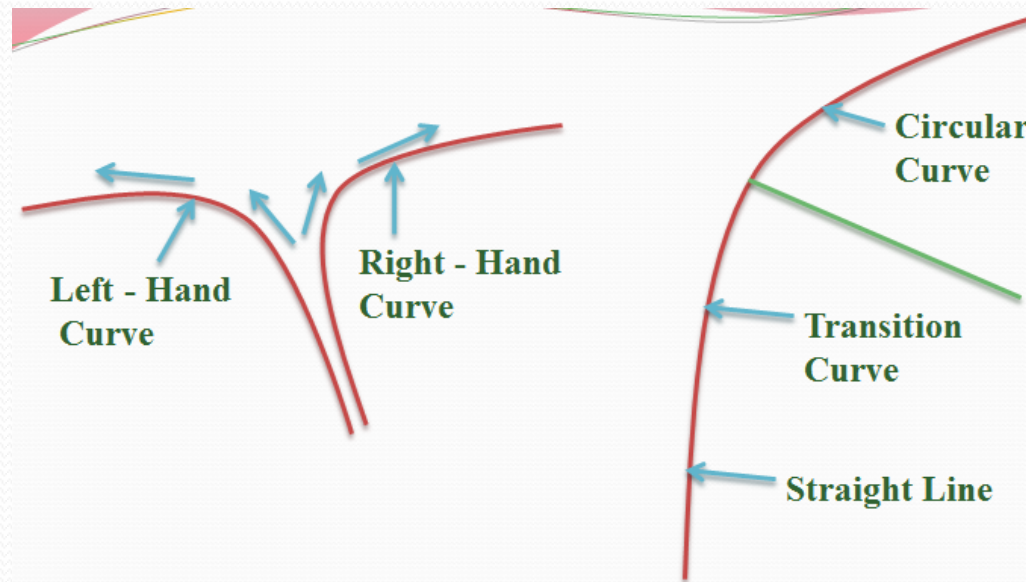
The distance between mid point of long chord (D) and the apex point C, is called **versed sine** .It is also called mid –ordinate (M).

- **Right hand curve :**

If the curve deflects to the right of the direction of the progress of survey, it is called the right-hand curve.

- **Left hand curve :**

If the curve deflects to the direction of the progress of survey , it is called left hand curve.



**Classification Of Curves**

# Designation of curve :

- The sharpness of the curve is designated by two ways :
  1. By radius (R)
  2. By degree of curvature (D)
- In this method the curve is known by the length of its radius (R).

For examples,

200 m curve means the curve having radius 200 m .

6 chain curve means the curve having radius equal to 6 chain .

- This method is used in England

## 2) By degree of curvature :

- In this method the curve is designated by degree .
- The degree of curvature can be defined by two ways :
  1. Chord definition
  2. Arc definition

# 1. Chord definition :

- The angle subtended at the centre of curve by a chord of 20 m is called **degree of curvature** .
- E.g.

If an angle subtended at the centre of curve by a chord of 20 m is  $5^\circ$ , the curve is called  $5^\circ$  curve .

# 2. Arc definition:

- The angle subtended at the centre of curve by an arc of 20 m length , is called **degree of curve** .
- This system is used in America , Canada , India , etc .

# Relation Between Radius And Degree Of curve

## A] By Chord Definition:-

- The angle subtended at the centre of curve by a chord of 20m is called degree of curve.

## B] By Arc definition:-

- The angle subtended at the centre of curve by an arc of 20m length is called degree of curve.

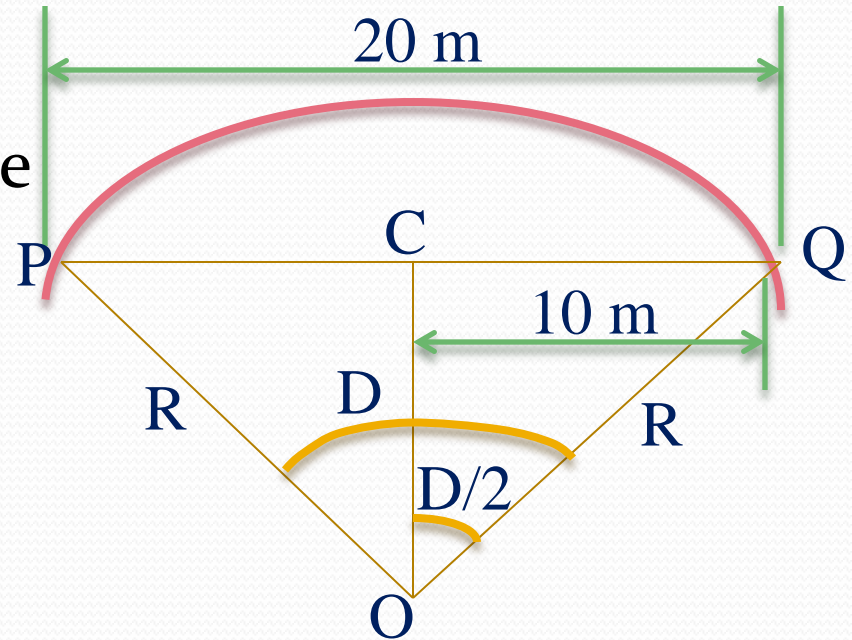
## A] By Chord Definition:-

- Here, R= radius of curve  
D= degree of curvature

From triangle PCO,

$$\sin \frac{D}{2} = \frac{10}{R}$$

$$\therefore R = \frac{10}{\sin \frac{D}{2}}$$





- When D is small,  $\sin D/2$  may be taken equal to  $D/2$ .

$$\therefore \sin \frac{D}{2} = \frac{D}{2}$$

$$\therefore R = \frac{10}{\frac{D}{2} \times \frac{\pi}{180}}$$

$$= \frac{10 \times 360}{\pi D}$$

$$= \frac{1145.92}{D}$$

$$= \boxed{\frac{1146}{D}}$$

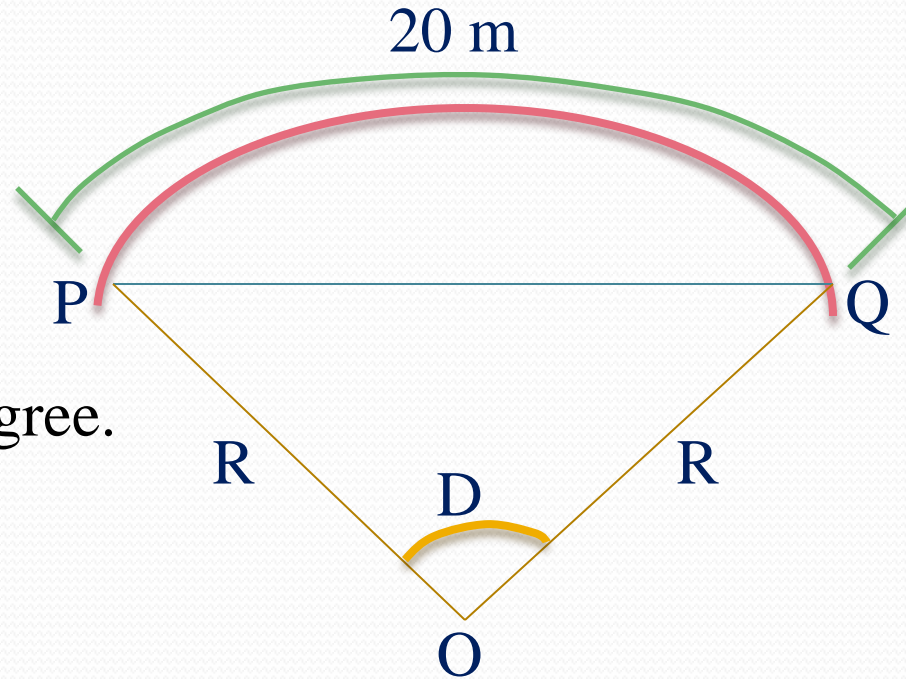
Where, D is in degree.

## B] By Arc Definition:-

- Here, R= radius of curve  
D= degree of curvature

$$\frac{2\pi R}{360} = \frac{20}{D}$$

Where, D is in degree.



$$\therefore R = \frac{20 \times 360}{2\pi D}$$

$$= \frac{1145.92}{D}$$

$$= \boxed{\frac{1146}{D}}$$

## Question .1

A circular curve has 200m radius and  $65^\circ$  deflection angle. What is its degree (a) by arc definition (b) chord definition also calculate

- i. Length of curve ii. Tangent length iii. Length of long chord iv. Apex distance and V. Mid ordinate

*olution* (a) *Arc definition*

Assuming a 30 m chord length,

$$R \times D \times \frac{\pi}{180^\circ} = 30$$

or

$$D = \frac{30 \times 180}{R \times \pi} = \frac{30 \times 180}{200 \times \pi} = 8.595$$

b) *Chord definition*

Assuming a 30 m chord length,

$$R = \frac{15}{\sin(D/2)} \text{ (but since } D \text{ is small, } \sin \frac{D}{2} = \frac{D}{2} \text{ radians)}$$

Hence,

$$R = \frac{15}{\frac{D}{2} \times \frac{\pi}{180}}$$

or

$$D = \frac{15 \times 2 \times 180}{\pi \times 200} = 8.595$$

- (i) Length of the curve,  $L = R \Delta \frac{\pi}{180^\circ} = 200 \times 65^\circ \times \frac{\pi}{180^\circ} = 226.89 \text{ m}$
- (ii) Tangent length,  $T = R \tan \frac{\Delta}{2} = 20 \tan \frac{65^\circ}{2} = 127.41 \text{ m}$
- (iii) Length of long chord,  $L = 2R \sin \frac{\Delta}{2} = 2 \times 200 \sin \frac{65^\circ}{2} = 214.92 \text{ m}$
- (iv) Apex distance =  $R \left( \sec \frac{\Delta}{2} - 1 \right) = 200 \left( \sec \frac{65^\circ}{2} - 1 \right) = 37.13 \text{ m}$
- (v) Mid-ordinate =  $R \text{ ver} = R \left( 1 - \cos \frac{\Delta}{2} \right) = 200 \left( 1 - \cos \frac{65^\circ}{2} \right) = 31.32 \text{ m}$



**THANK YOU**