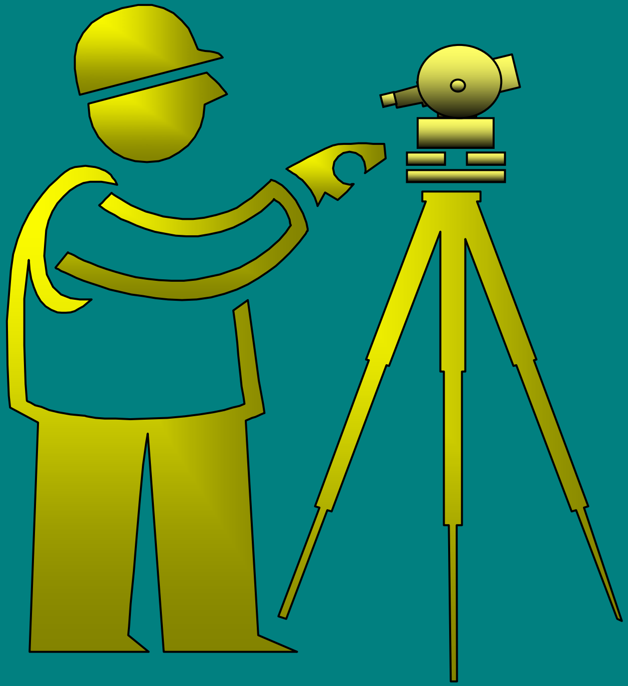
Arc Setting Out

The purpose of this Instruction is to enable you to calculate and set out Circular and Elliptical arcs.



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1. Short radius circular arcs by chord & offset
2. Short radius ellipses by chord & offset
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Vertical Alignment

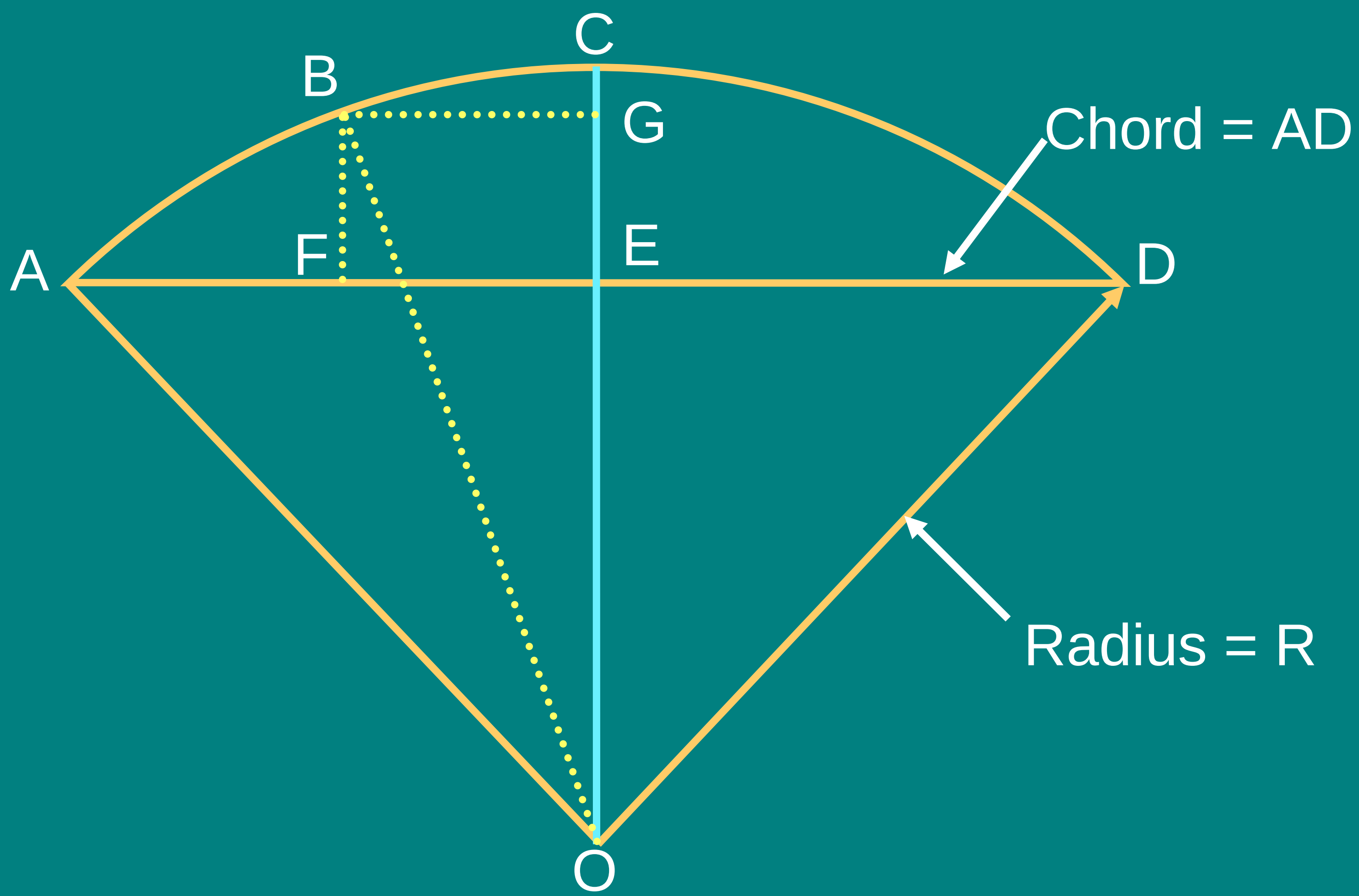
1. Simple Parabola

1. Short Radius Circular Arc

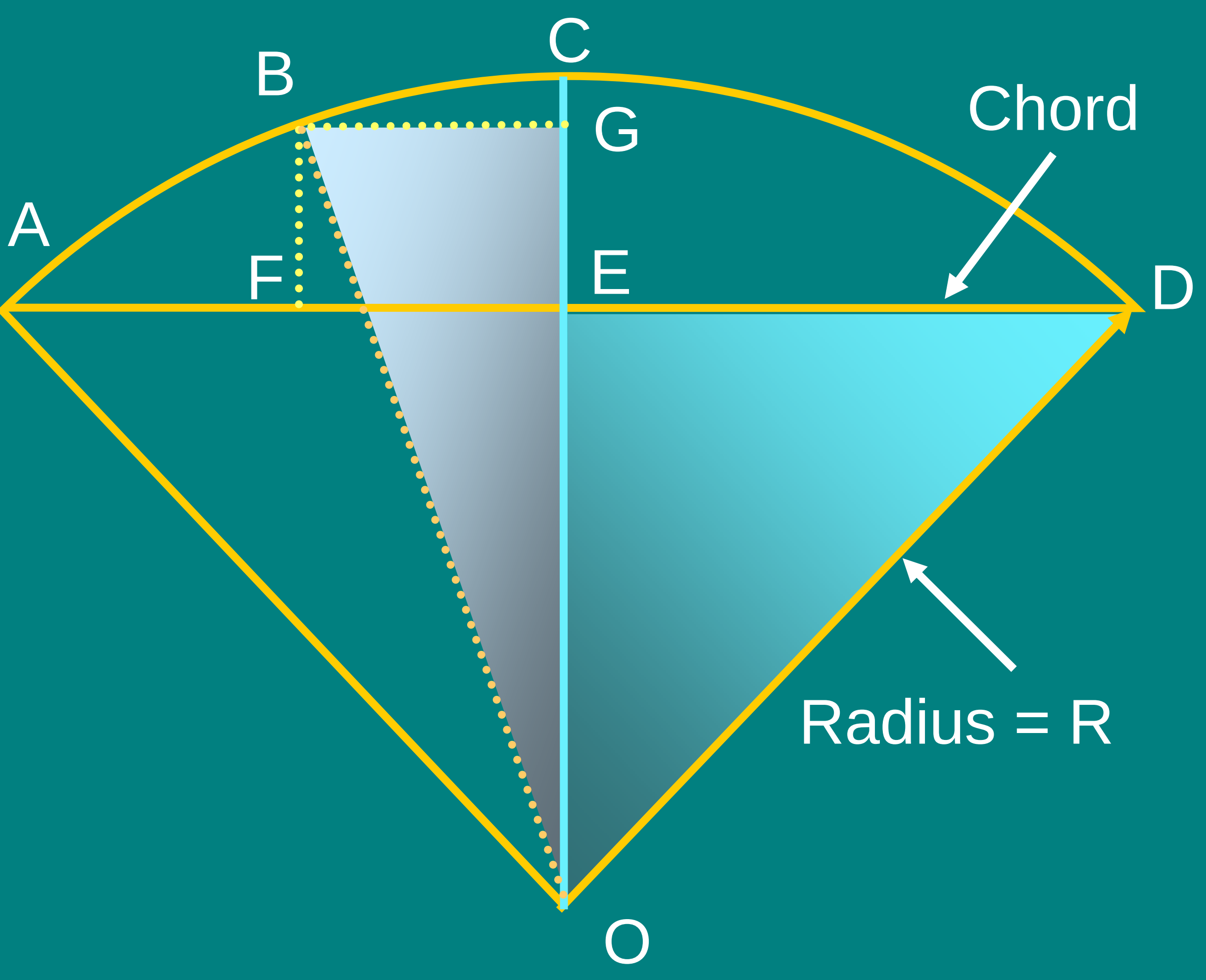
The Requirements

- Given a Chord AD, and a Radius R.
- Calculate Square Offsets to the Arc from the Chord at Suitable Intervals along the Chord.

Short Radius Circular Arc



Calculate Offsets



In triangle O, E, D

$EO^2=R^2-ED^2$

<u>CE=R-EO</u>

In triangle G,B,O

BG = EF

$GO^2=R^2-BG^2$

<u>BF=GE=GO-EO</u>

Repeat for variations in BG

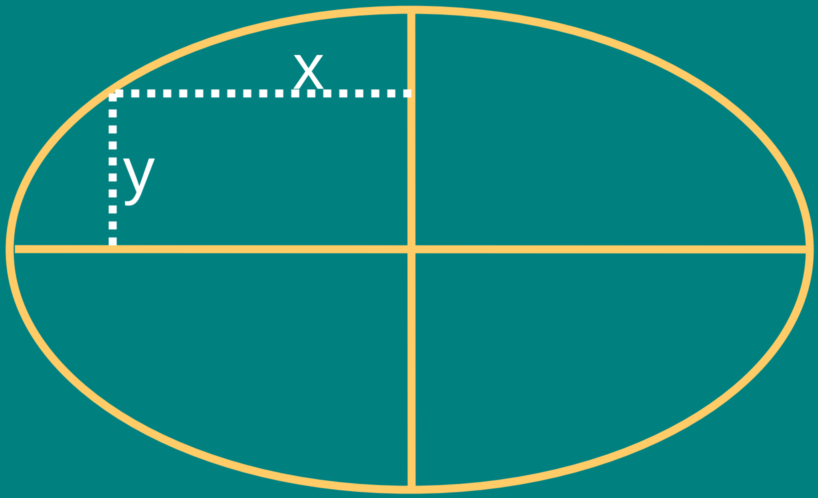
Arc Setting Out

This is the end of the circular arc by chord & offset.

2. Short Radius Ellipse

The Requirements

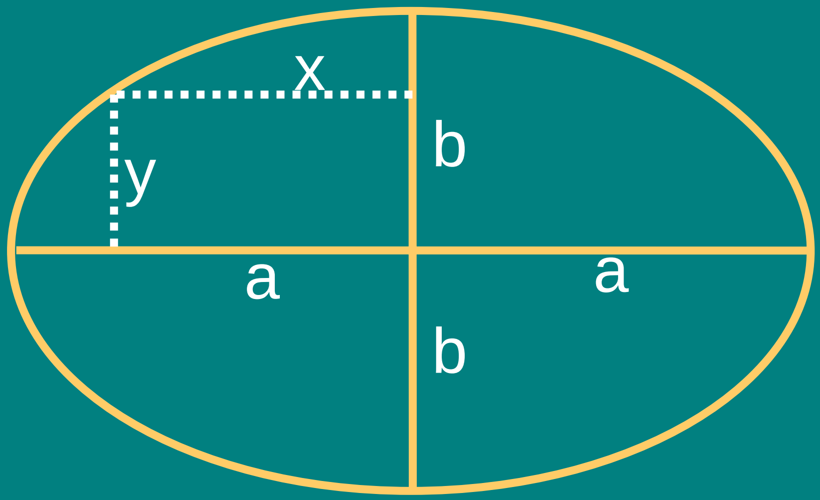
- Given the major and minor axes,
- Calculate Square Offsets to the Arc From the Chord at Suitable Intervals along the Chord.



Short Radius Ellipse

- Ellipse formula
- $(x^2/a^2) + (y^2/b^2) = 1$

- Where: -
- a = semi-major axis.
- b = semi-minor axis.
- x = required distance.
- y = corresponding offset.

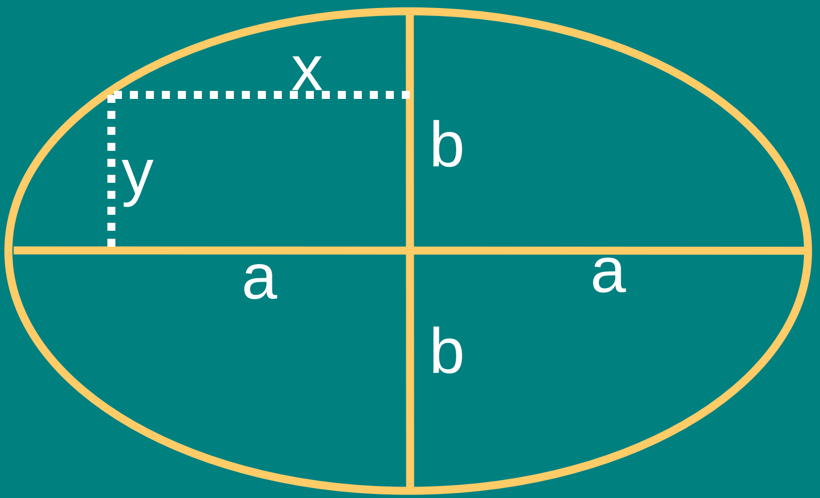


Calculate Offsets.

Ellipse formula.

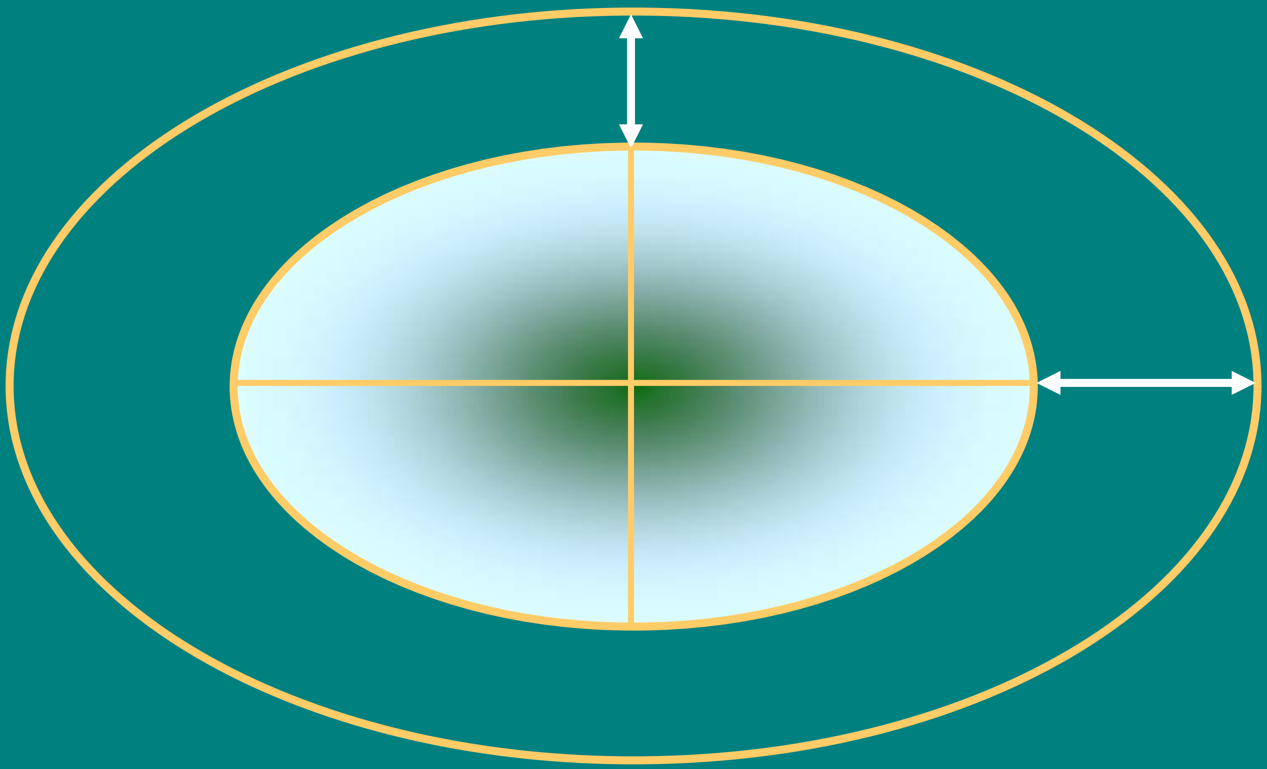
1. $(x^2/a^2) + (y^2/b^2) = 1.$
2. $y^2/b^2 = 1 - (x^2/a^2).$
3. $y^2 = (1 - (x^2/a^2)) \times b^2.$

Repeat for variations in x



Warning

Concentric Ellipses are not Parallel.

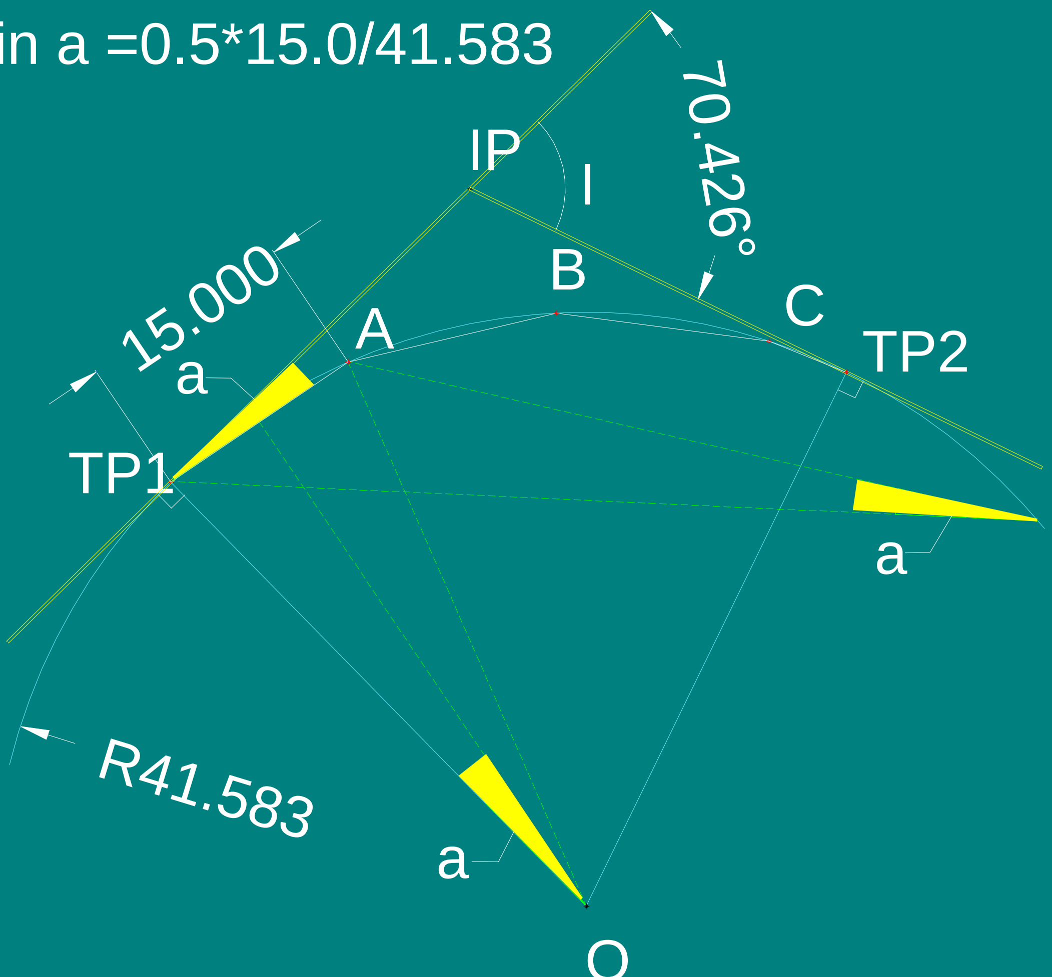


Ellipse Setting Out

This is the end of the elliptical arc by chord & offset.

3. Arcs by Deflection Angles

Sin a =0.5*15.0/41.583



Given: -

R = 41.583m.

I = 70.426º

IP Location

WCB TP1 to I

Calculate: -

Setting Out info.

Geometry

In Quadrilateral TP1-IP-TP2-O,

TP1 = 90º, TP2 = 90º, therefore IP + O = 180º.

<u>But</u> IP + 70.426º = 180º,

<u>therefore</u> O = 70.426º

Then TP1 to IP = TP2 to IP

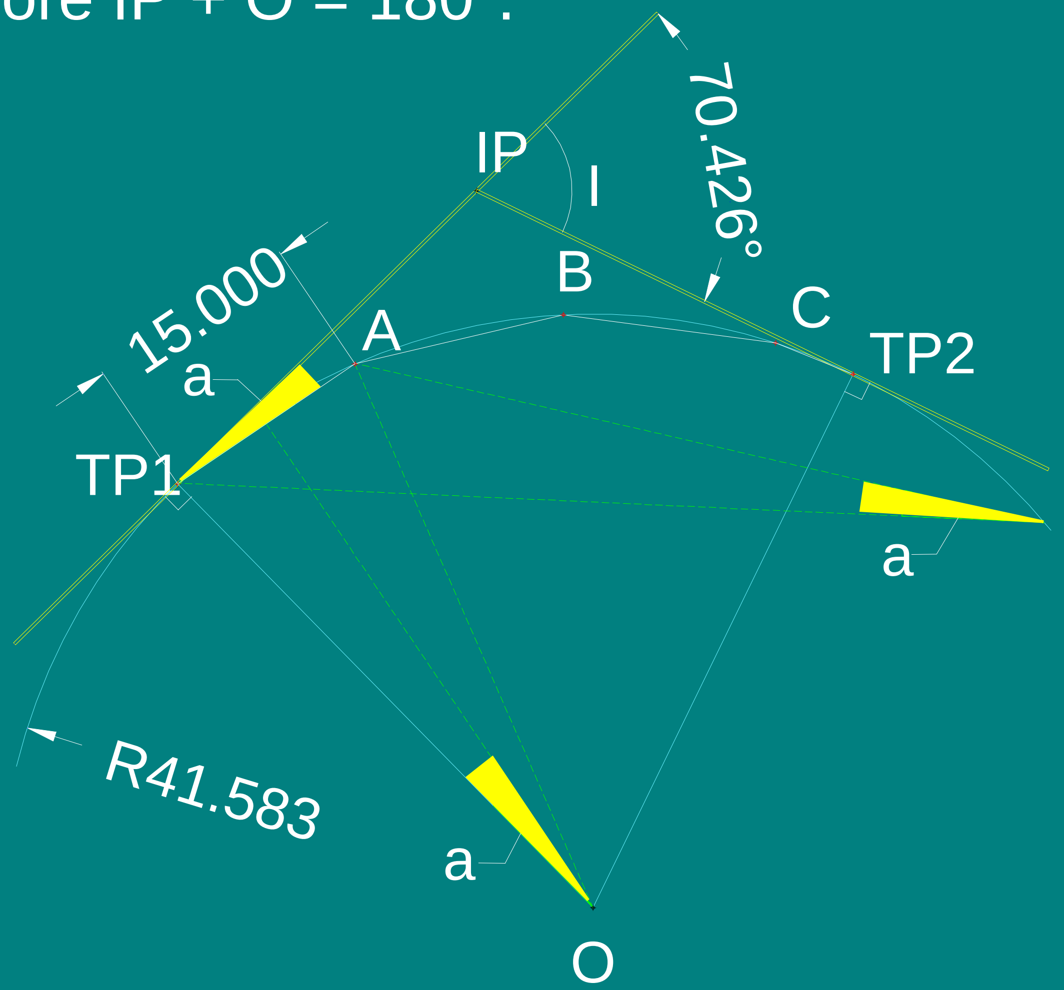
= R **x** tan (70.426º ***/***2)

If chord = 15.000,

a = IP-TP1-A

= $\sin^{-1}(7.5/41.583)$

= 10.391º

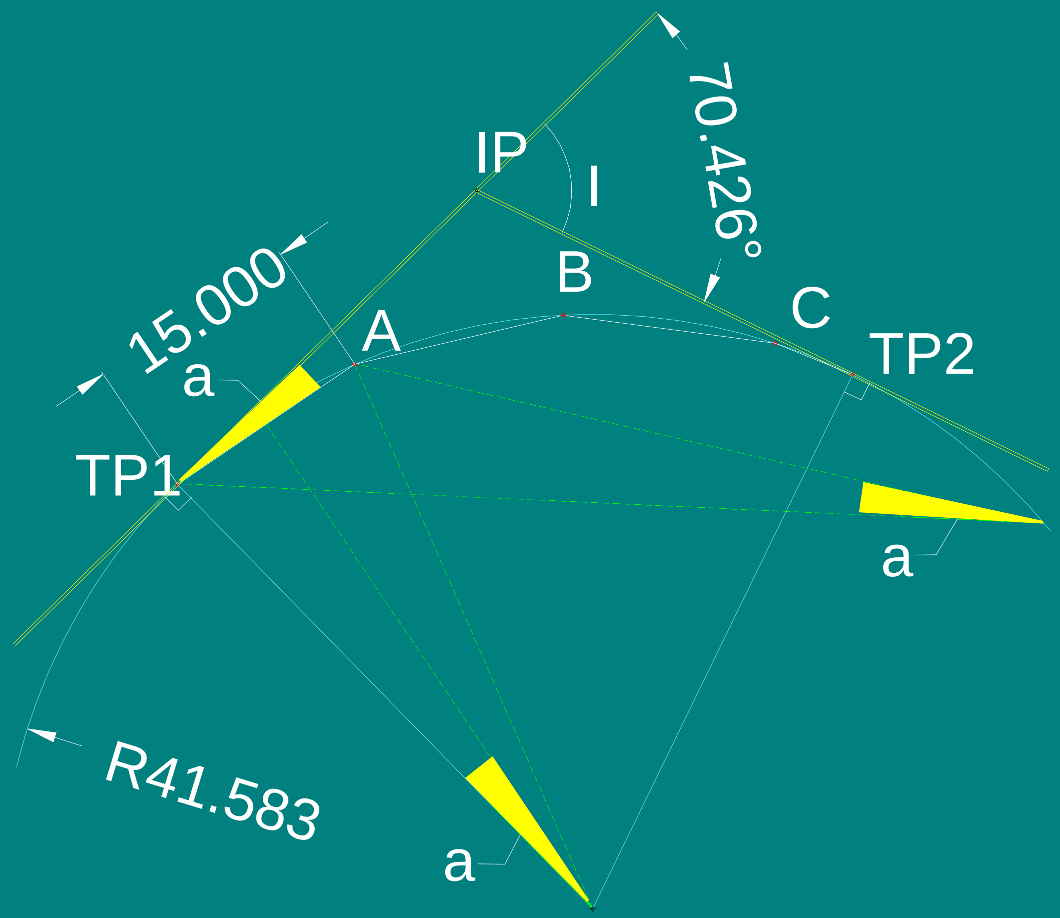


Setting Out

IP-TP1-B = 2**a** = 20.782º

IP-TP1-C = 3**a** = 31.173º

TP1 to A = A to B =B to C



Similarly calculate the residual C to TP2.

IP-TP1-TP2 =70.426º/2
= 35.213º

C-TP1 TP2
= 35.213º- 31.173º

Etc.

Deflection Angles

This is the end of the deflection angles section

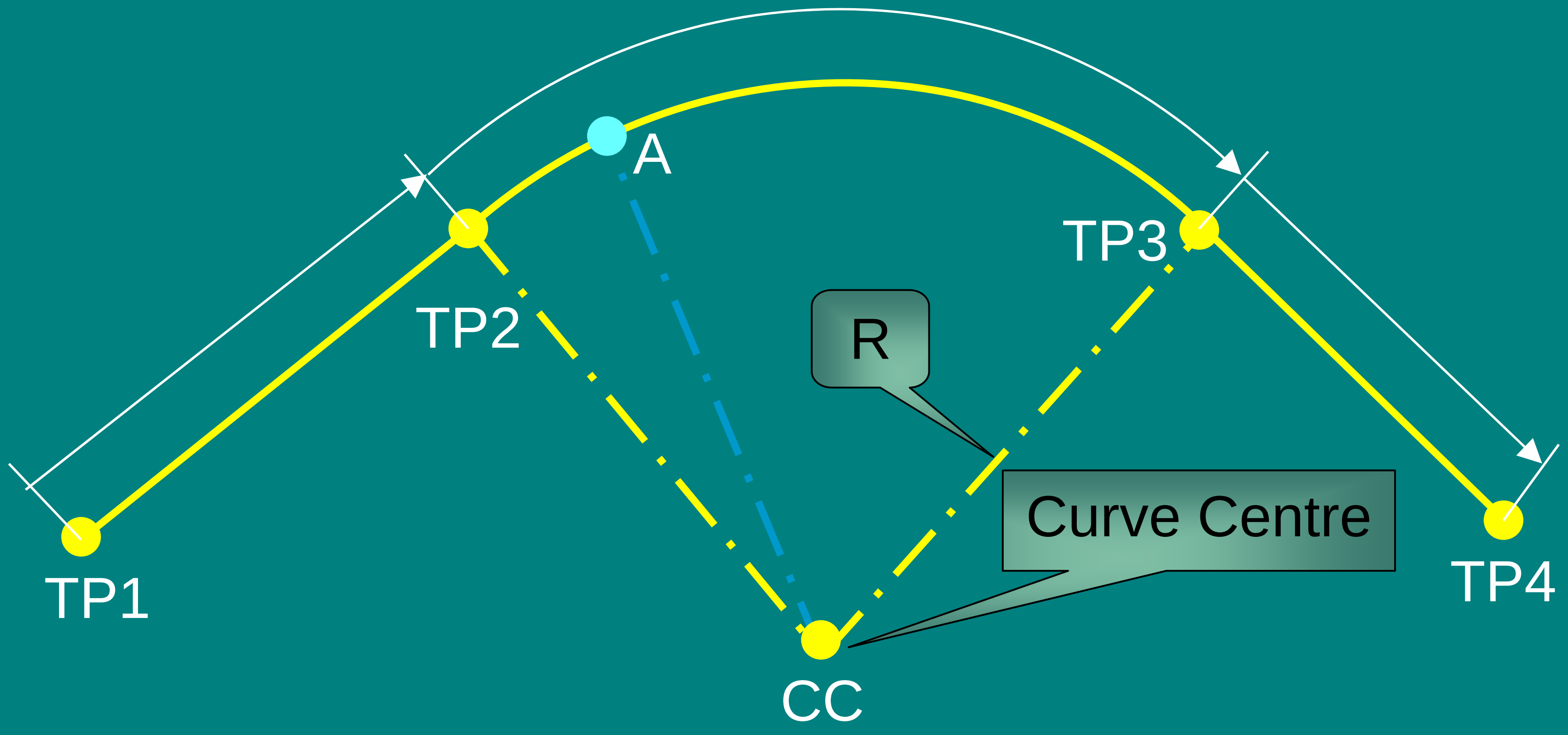
4. Co-ordinate Setting Out

- All large radius curves are amenable to setting out by co-ordinates.
- It is probably just as easy to calculate co-ordinates as it is to calculate curve elements.
- It is easier to set out as the instrument does not need to be set up on the curve. Intervisibility is the only requirement

Design Line Chainage

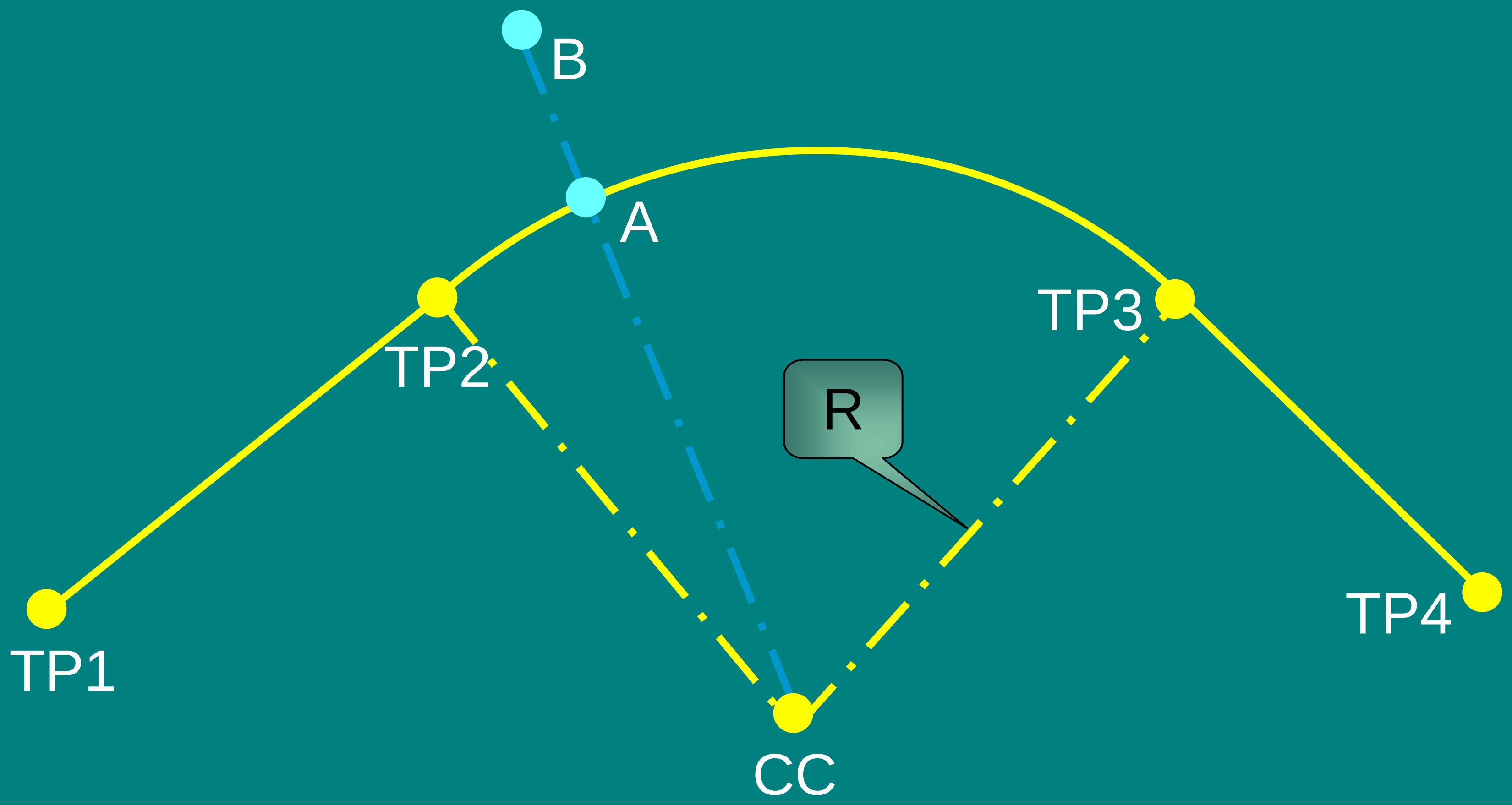
Chainage is the longitudinal distance along a design line.

This design line is TP1,TP2, TP3, TP4, and it could be a carriageway centre line.



Chainage and Offset

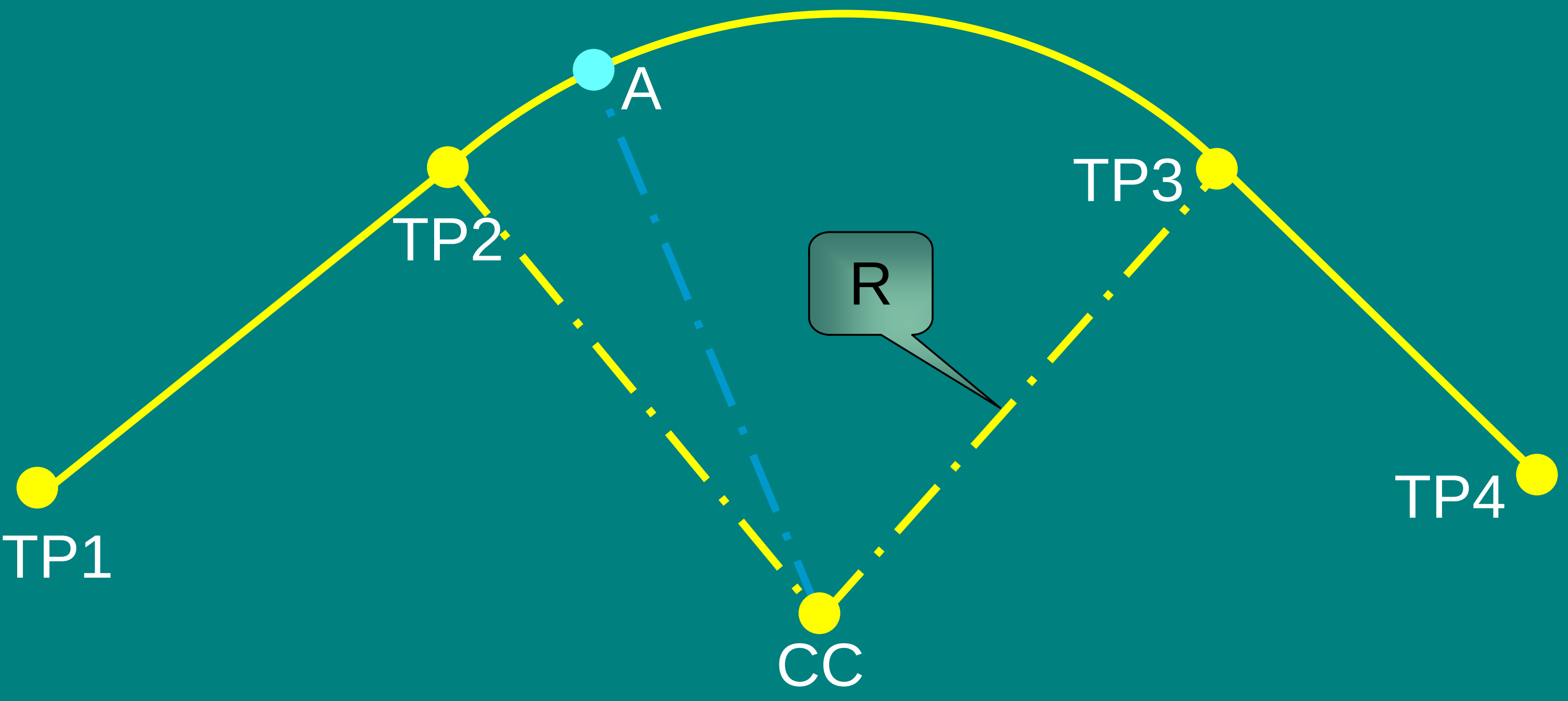
An offset is the distance perpendicular to the design line, and could be the edge of the carriageway.



Design Lines

Design lines often contain multiple straights, circular arcs, and spirals

The coordinates of the TP’s and CC’s are either provided, or can be derived from the chainages and geometry given by the designer.



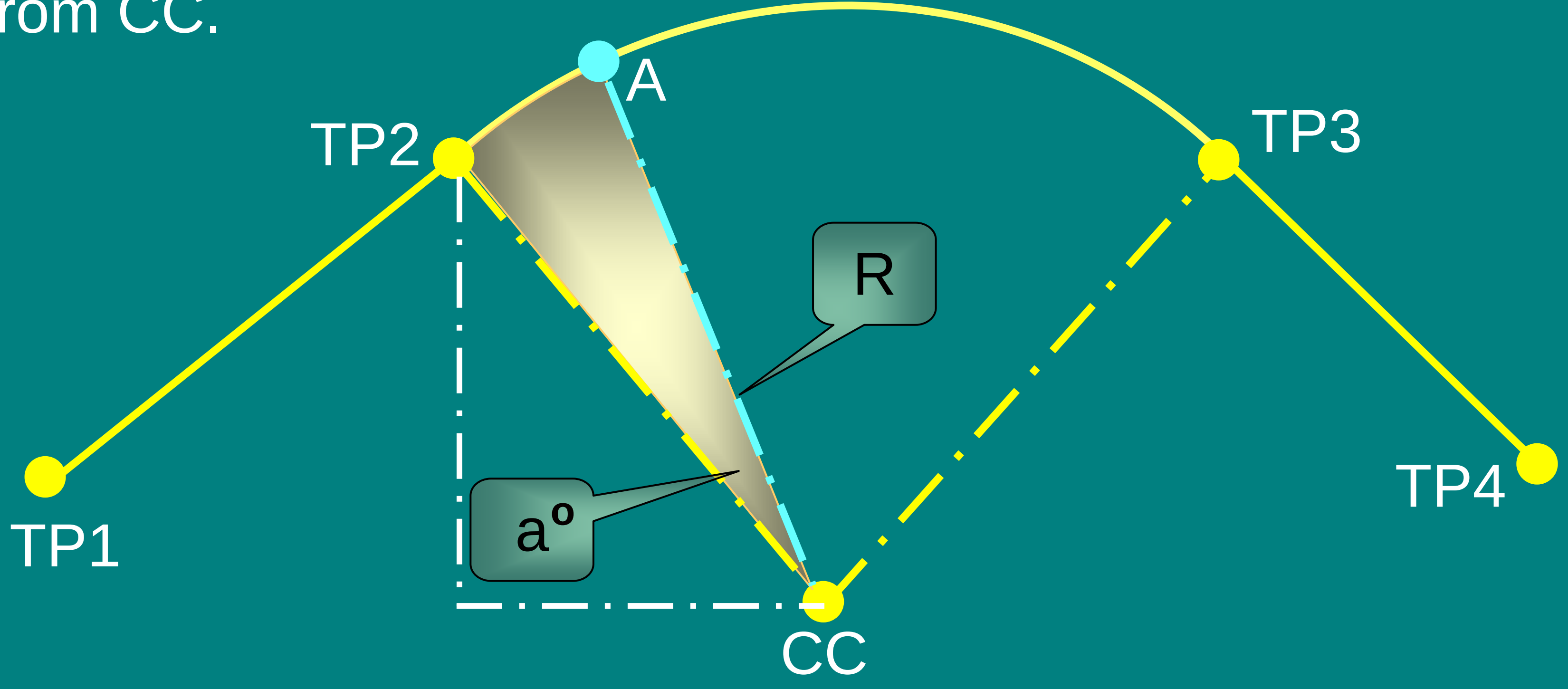
Co-ordinate Setting Out

Given the chainages of point A and TP2,

Angle a = (Chainage A – Chainage TP2)/(2πR) x 360.

AZ (CC to A) = AZ(CC to TP2) + Angle a.

R is known, therefore the coordinates of A can be calculated from CC.



Coordinate Setting out

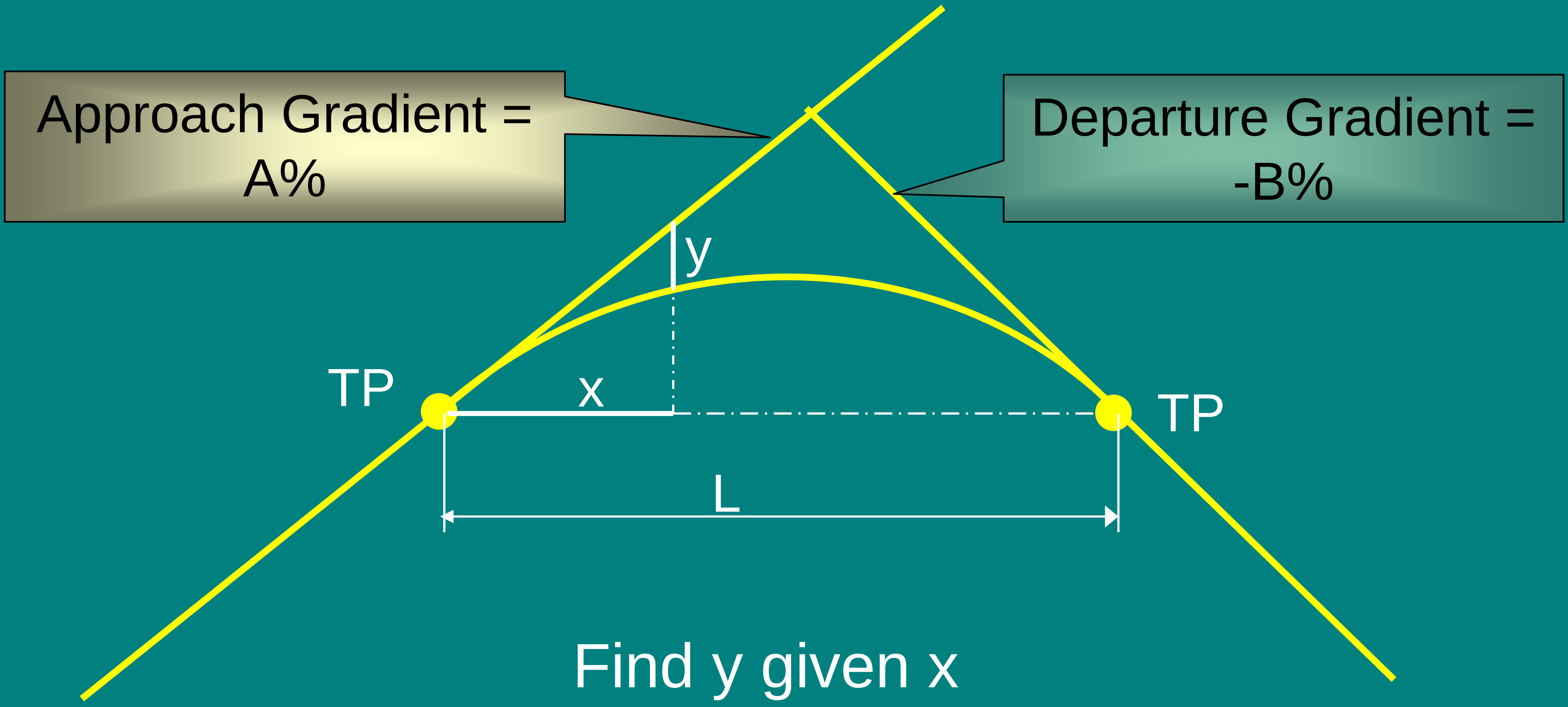
This is the end of the horizontal alignment section

Vertical Alignment

- Vertical curves need to be inserted at peaks and troughs on highways to smooth out gradient changes and provide adequate sight lines.

- Generally, the simple parabola is used as the rate of change of gradient is constant.

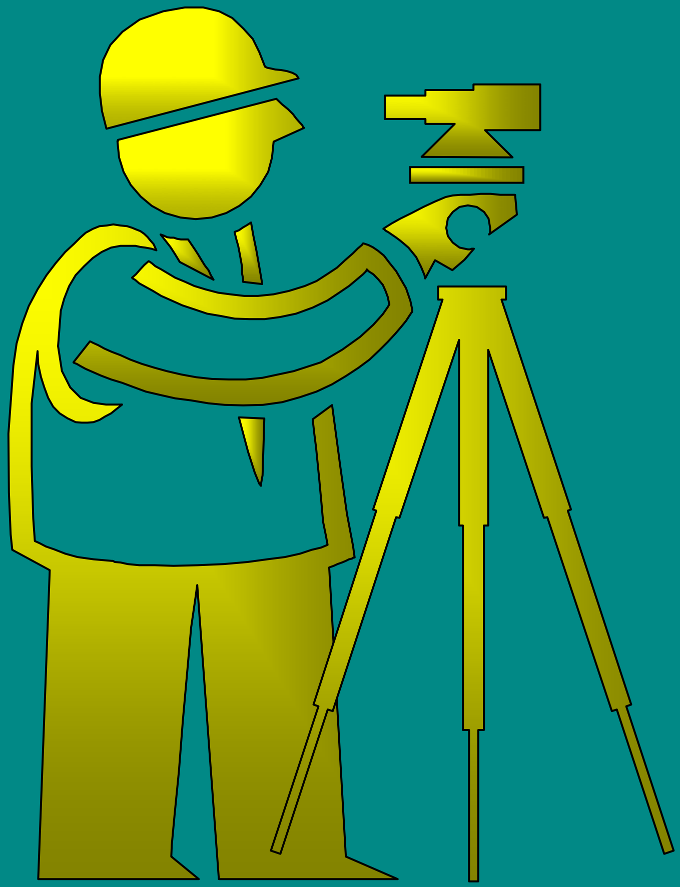
1 Vertical Curve, Parabola



Find y given x

$$y = x^2 * (A-B)/(200L)$$

THE END



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- We will not consider short radius, (< 5metres), arcs where the centre is accessible, and where it is simply a matter of placing zero on a measuring tape, and striking an arc of the desired radius

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- The assumption is that the centre of the arc is not accessible.

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- Construct OC bisecting AD at E, (90 degrees).
- Choose a chord distance EF = BG.
- Join B to O = radius R.

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- Substitute different values of x in the above equation to obtain corresponding values of y.

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- Note for designers.
- If you design a staircase with an elliptical stairwell, and elliptical stair walls, the stair treads will be different lengths.
- Note for setting out.
- If you have to set out an elliptical feature you cannot set out an offset ellipse. You must set out the actual feature, and then mark out suitable offsets to the original lines.

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- Traditional setting out method for long radius curves using theodolite and tape.
- TP1 and TP2 are the tangent points, where straight meets curve.
- O -TP1-IP = 90 degrees, O -TP2-IP = 90 degrees
- O is the centre of the circle.
- IP is the Intersection Point of the projected straights.
- I is the intersection angle.

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- Decide on the chord length, TP1 to A, A to B, B to C, say 15.000m.
- The angle between a chord and a tangent = the angle in the opposite segment.
- The angle subtended by a chord at the circumference of a circle is twice that subtended at the centre.

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- TP's are tangent TP's are tangent points
- CC's are curve centres.
- It is usual to have zero chainage at the start of the design line.
- ***If the chainage of TP1 =100,***
- Then the chainage of TP2 = 100 + distance TP1 to TP2,
- And the chainage of TP3 = chainage TP2 plus arc length TP2 to TP3,
- And the chainage of TP4 = chainage TP3 plus the distance TP3 to TP4.
- Thus the chainage of A = chainage TP2 plus the arc length TP2 to A

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- B is an offset at chainage point A. The chainage must be specified for each offset.
- Obviously offsets can be either side of a design line.
- They are usually signed negative when to the left of an observer looking in the direction of increasing chainage,
- And signed positive when to the right.

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- A spiral is a "Transition Curve", and is inserted between a straight and a circular arc to overcome the sudden change of direction that would otherwise be necessary at the end of the straight.
- The definition of a spiral is "a curve whose radius is inversely proportional to its length".
- Thus if a spiral were to be inserted between TP2 and A above, its radius at TP2 would be infinite, and at A it would be R.
- ***We will not be considering spirals in this course.***

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- AZ = Whole Circle Bearing
- **To calculate AZ (CC to TP2)**
- Let dx = X (TP2) – X (CC), and Let dy = Y (TP2) – Y (CC),
- Quadrant Bearing (CC to TP2) = $\tan^{-1}(dx/dy)$.
- If dx is positive and dy is positive, AZ = Quadrant bearing.
- If dx is positive and dy is negative, AZ = 180 - Quadrant bearing.
- If dx is negative and dy is negative, AZ = 180 + Quadrant bearing.
- If dx is negative and dy is positive, AZ = 360 - Quadrant bearing.

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- Vertical curves are usually designed: -
- To allow a driver to just see an object on the ground within his stopping distance,
- To minimise passenger discomfort due to vertical acceleration,
- To provide adequate clearance between the carriageway surface and overhead structures on sag curves.
- Obviously the design speed of the road is a major factor in the calculations.

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Example
If L = 40.0, and A = 5.5%, and B = -4.3%
When x = 8, y = 0.0784
When x = 12, y = 0.1764
When x = 20, y = 0.4900

End of Notes