APPENDIX B

Contents

For additional references and formulae, see VDOT Construction Manual, Appendix D

METRIC CONVERSIONS

*****	1 meter (m)	=	39.37 inches (U. S. Survey Foot)
	1 meter (m)	=	39.37007874 inches (International Foot)
	1 meter (m)	=	3.280833333333 feet (U. S. Survey Foot)
	1 meter (m)	=	3.280839895 feet (International Foot)
	1 kilometer (km)	=	0.62136995 mile (per U. S. Survey Foot)
	1 hectare (ha)	=	2.471044 acres (per U. S. Survey Foot)
	1 hectare (ha)	=	2.471054 acres (per International Foot)
*	1 meter (m)	=	1,000 millimeters (mm)
*	1 kilometer (km)	=	1,000 meters (m)
*	1 hectare (ha)	=	10,000 sq. meters (m^2)

ADDITIONAL CONVERSIONS

	1 U. S. Survey Foot	=	1.000002 International Foot
	1 U.S. Survey acre	=	1.000004 acre (per International Foot)
*	1 rod, pole, perch	=	16½ feet (U. S. Survey Foot)
*	1 chain (Gunter's)	=	66 feet (U. S. Survey Foot)
*	1 chain (Gunter's)	=	4 rods or 100 links
*	1 link	=	7.92 inches (U. S. Survey Foot)
*	1 furlong	=	660 U.S. Survey Feet or 10 chains
*	1 mile	=	5,280 feet (U. S. Survey Foot)
*	1 mile	=	8 furlongs or 80 chains or 320 rods
*	1 acre	=	43,560 $feet^2$ (per U. S. Survey Foot)
*	1 station	=	100 feet (ft) or 100 meters (m)
*	1 staking interval	=	50 feet (ft) or 20 meters (m)

*** Denotes exact conversion values. All others correct to figures shown.**

PRECISION OF INDIVIDUAL MEASUREMENTS

Horizontal Measurements	-	nearest 0.005 feet with EDM/Total Station
		nearest 0.01 feet with steel chain
		nearest 0.02 feet with cloth/fiberglass tape
Vertical Measurements	-	nearest 0.01 feet on bridges
		nearest 0.01 feet on existing pavement
		nearest 0.05 feet on natural ground
Trig Leveling/DTM	-	nearest 0.01 feet for H.I and target height

NOTE: All surveying measurements will be made in feet and decimals of a foot.

CONVERSION CHART (International Foot)

decimal inches	(in) inches	(cm) centimeters		(ft) feet	(cm) centimeters	(m) meters	(km) kilometer
0.0313	1/32	0.079		1	30.48	0.3048	0.000304
0.0625	1/16	0.159		2	60.96	0.6096	0.000609
0.0938	3/32	0.238		3	91.44	0.9144	0.000914
0.1250	1/8	0.318		4	121.92	1.2192	0.001219
0.1563	5/32	0.397		5	152.40	1.5240	0.001524
0.1875	3/16	0.476		6	182.88	1.8288	0.001829
0.2188	7/32	0.556		7	213.36	2.1336	0.002134
0.2500	1/4	0.635		8	243.84	2.4384	0.002438
0.2813	9/32	0.714		9	274.32	2.7432	0.002743
0.3125	5/16	0.794		10	304.80	3.0480	0.003048
0.3438	11/32	0.873		20	609.60	6.0960	0.006096
0.3750	3/8	0.953		30	914.40	9.1440	0.009144
0.4063	13/32	1.032		40	1219.20	12.1920	0.012192
0.4375	7/16	1.111		50	1524.00	15.2400	0.015240
0.4688	15/32	1.191		60	1828.80	18.2880	0.018288
0.5000	1/2	1.270		70	2133.60	21.3360	0.021336
0.5313	17/32	1.349		80	2438.40	24.3840	0.024384
0.5625	9/16	1.429		90	2743.20	27.4320	0.027432
0.5938	19/32	1.508		100	3048.00	30.4800	0.030480
0.6250	5/8	1.588		200	6096.00	60.9600	0.060960
0.6563	21/32	1.667		300	9144.00	91.4400	0.091440
0.6875	11/16	1.746		400	12192.00	121.9200	0.121920
0.7188	23/32	1.826		500	15240.00	152.4000	0.152400
0.7500	3/4	1.905		600	18288.00	182.8800	0.182880
0.7813	25/32	1.984		700	21336.00	213.3600	0.213360
0.8125	13/16	2.064		800	24384.00	243.8400	0.243840
0.8438	27/32	2.143		900	27432.00	274.3200	0.274320
0.8750	7/8	2.223		1000	30480.00	304.80	0.3048
0.9063	29/32	2.302		2000	60960.00	609.60	0.6096
0.9375	15/16	2.381		3000	91440.00	914.40	0.9144
0.9688	31/32	2.461		4000	121920.00	1219.20	1.2192
1.0000	1	2.540		5000	152400.00	1524.00	1.5240
2.0000	2	5.080		6000	182880.00	1828.80	1.8288
3.0000	3	7.620		7000	213360.00	2133.60	2.1336
4.0000	4	10.160		8000	243840.00	2438.40	2.4384
5.0000	5	12.700		9000	274320.00	2743.20	2.7432
6.0000	6	15.240		10000	304800.00	3048.00	3.0480
7.0000	7	17.780					
8.0000	8	20.320					
9.0000	9	22.860					
10.0000	10	25.400					
11.0000	11	27.940					
12.0000	12	30.480					

MINUTES & SECONDS to DECIMALS of a DEGREE

	Minutes	Seconds			Minutes	Seconds
1	0.016667	0.000278		31	0.516667	0.008611
2	0.033333	0.000556		32	0.533333	0.008889
3	0.050000	0.000833		33	0.550000	0.009167
4	0.066667	0.001111		34	0.566667	0.009444
5	0.083333	0.001389		35	0.583333	0.009722
6	0.100000	0.001667		36	0.600000	0.010000
7	0.116667	0.001944		37	0.616667	0.010278
8	0.133333	0.002222		38	0.633333	0.010556
9	0.150000	0.002500		39	0.650000	0.010833
10	0.166667	0.002778		40	0.666667	0.011111
11	0.183333	0.003056		41	0.683333	0.011389
12	0.200000	0.003333		42	0.700000	0.011667
13	0.216667	0.003611		43	0.716667	0.011944
14	0.233333	0.003889		44	0.733333	0.012222
15	0.250000	0.004167		45	0.750000	0.012500
16	0.266667	0.004444		46	0.766667	0.012778
17	0.283333	0.004722		47	0.783333	0.013056
18	0.300000	0.005000		48	0.800000	0.013333
19	0.316667	0.005278		49	0.816667	0.013611
20	0.333333	0.005556		50	0.833333	0.013889
21	0.350000	0.005833		51	0.850000	0.014167
22	0.366667	0.006111		52	0.866667	0.014444
23	0.383333	0.006389		53	0.883333	0.014722
24	0.400000	0.006667		54	0.900000	0.015000
25	0.416667	0.006944		55	0.916667	0.015278
26	0.433333	0.007222		56	0.933333	0.015556
27	0.450000	0.007500		57	0.950000	0.015833
28	0.466667	0.007778		58	0.966667	0.016111
29	0.483333	0.008056		59	0.983333	0.016389
30	0.500000	0.008333				

Example: To convert 8° 49’ 27” to decimal of a degree.

Using the chart above:

8° = 8.000000

49’ = 0.816667

27” = 0.007500

Add the three numbers to get the result…..8.824167°

Example: To convert 8.824167° to degrees, minutes and seconds.

First, we know 8.00000 = 8° and 0.824167 degree

Next multiply: (0.824167 degree) * (60 minutes/degree) = 49.45020 minutes.

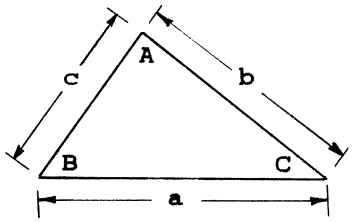
Now, we know we have 49 minutes and 0.450020 minute.

Next multiply: (0.450020 minute) * (60 seconds/minute) = 27.0012 seconds

For the result: 8° 49’ 27”

TRIANGLE FORMULAE

Law of sines	$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$
Law of cosines	$a^2 = b^2 + c^2 - 2bc \cos A$ $b^2 = a^2 + c^2 - 2ac \cos B$ $c^2 = a^2 + b^2 - 2ab \cos C$
Law of tangents	$\frac{a - b}{a + b} = \frac{\tan 1/2 (A-B)}{\tan 1/2 (A+B)}$

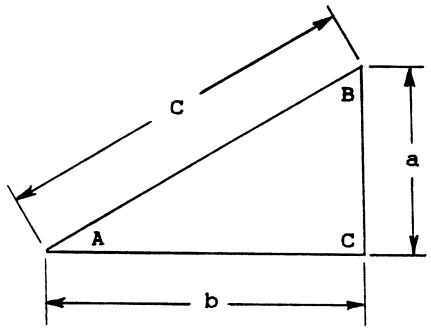


Find	Given	Formula
A	BC	$180^\circ - (B+C)$
sin A	acC	$\frac{a \times \sin C}{c}$
sin A	abB	$\frac{a \times \sin B}{b}$
cos A	abc	$\frac{b^2 + c^2 - a^2}{2bc}$
tan A	acB	$\frac{a \times \sin B}{c - (a \times \cos B)}$
tan A	abC	$\frac{a \times \sin C}{b - (a \times \cos C)}$
B	AC	$180^\circ - (A + C)$
sin B	abA	$\frac{b \times \sin A}{a}$
sin B	bcC	$\frac{b \times \sin C}{c}$
cos B	abc	$\frac{c^2 + a^2 - b^2}{2ac}$
tan B	bcA	$\frac{b \times \sin A}{c - (b \times \cos A)}$
C	AB	$180^\circ - (A + B)$
sin C	acA	$\frac{c \times \sin A}{a}$

Find	Given	Formula
sin C	bcB	$\frac{c \times \sin B}{b}$
cos C	abc	$\frac{a^2 + b^2 - c^2}{2ab}$
tan C	bca	$\frac{c \times \sin A}{b - (c \times \cos A)}$
tan C	acB	$\frac{c \times \sin B}{a - (c \times \cos B)}$
a	cAC	$\frac{c \times \sin A}{\sin C}$
a	bAB	$\frac{b \times \sin A}{\sin B}$
a	bcA	$\sqrt{b^2 + c^2 - (2bc \times \cos A)}$
b	aAB	$\frac{a \times \sin B}{\sin A}$
b	cBC	$\frac{c \times \sin B}{\sin C}$
b	acB	$\sqrt{a^2 + c^2 - (2bc \times \cos B)}$
c	aAC	$\frac{a \times \sin C}{\sin A}$
c	bBC	$\frac{b \times \sin C}{\sin B}$
c	abC	$\sqrt{a^2 + b^2 - (2ab \times \cos C)}$

RIGHT TRIANGLE FORMULAE

$\text{SIN} = \frac{\text{Opposite Side}}{\text{Hypotenuse}}$	$\text{TAN} = \frac{\text{Opposite Side}}{\text{Adjacent Side}}$	$\text{SEC} = \frac{\text{Hypotenuse}}{\text{Adjacent Side}}$
$\text{COS} = \frac{\text{Adjacent Side}}{\text{Hypotenuse}}$	$\text{COT} = \frac{\text{Adjacent Side}}{\text{Opposite Side}}$	$\text{CSC} = \frac{\text{Hypotenuse}}{\text{Opposite Side}}$

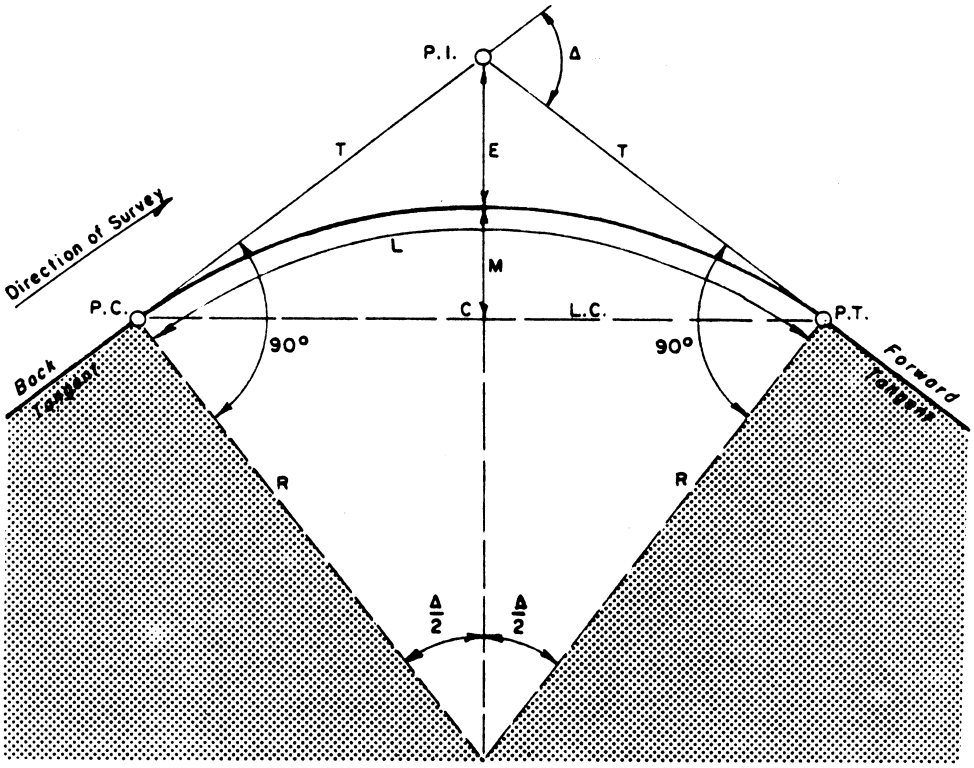


Find	Given	Formula
SIN A	Sides a, c	$\frac{a}{c}$
SIN A	Cos A, Tan A	Cos A Tan A
SIN A	Cos A	$\sqrt{1 - \text{Cos}^2 A}$
COS A	Sides b, c	$\frac{b}{c}$
COS A	Sin A, Tan A	$\frac{\text{Sin A}}{\text{Tan A}}$
COS A	Sin A	$\sqrt{1 - \text{Sin}^2 A}$
SIDE a	Sides b, c	$\sqrt{c^2 - b^2}$
SIDE a	Side c, Sin A	c Sin A
SIDE a	Side b, Tan A	b Tan A
SIDE b	Sides a, c	$\sqrt{c^2 - a^2}$
SIDE b	Side c, Cos A	c Cos A

Find	Given	Formula
SIDE b	Side a, Tan A	$\frac{a}{\text{Tan A}}$
SIDE c	Sides a, b	$\sqrt{a^2 + b^2}$
SIDE c	Side a, Sin A	$\frac{a}{\text{Sin A}}$
SIDE c	Side b, Cos A	$\frac{b}{\text{Cos A}}$
TAN A	Sin A, Cos A	$\frac{\text{Sin A}}{\text{Cos A}}$
TAN A	Sides a, b	$\frac{a}{b}$
ANGLE A	Angles B, C	C - B
ANGLE B	Angles A, C	C - A
ANGLE C	Angles A, B	A + B

FIGURE E-4
REFERENCE FORMULAS-90° TRIANGLE

HORIZONTAL CURVE FORMULAE



FORMULAS FOR ARC DEFINITION

$\Delta = \frac{DL}{100}$

$D = \frac{5729.58}{R}$

$T = R \tan \frac{\Delta}{2}$

$L = \frac{100\Delta}{D}$

$R = \frac{5729.58}{D}$

$E = T \tan \frac{\Delta}{4} = R \sec \frac{\Delta}{2} - R = R \operatorname{exsec} \frac{\Delta}{2}$

$M = R \operatorname{vers} \frac{\Delta}{2}$

$L.C. = 2R \sin \frac{\Delta}{2}$

Locating the P.C. and P.T.

Sta. P.C. = Sta. P.I. - T

Sta. P.T. = Sta. P.C. + L

LEGEND

P.I. – Point of Intersection

P.C. – Point of Curvature

P.T. – Point of Tangency

Δ – Deflection Angle Between the Tangents

T – Tangent Distance

E – External Distance

R – Radius of the Circular Arc

M – Middle Ordinate

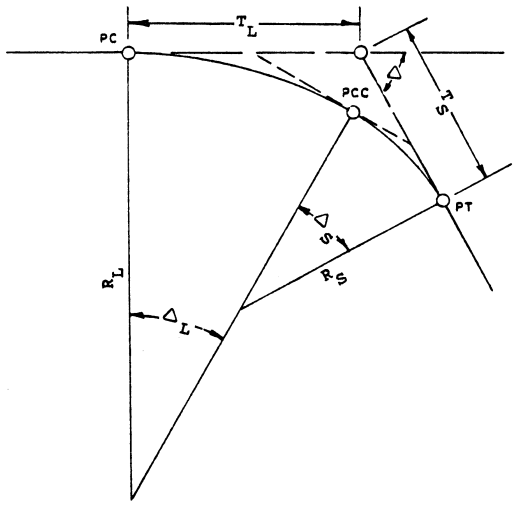
L.C. – Long Chord (Distance Between P.C. and P.T.)

C – Midpoint of Long Chord

D – Degree of Curvature

L – Length of Curve

COMPOUND CURVE FORMULAE



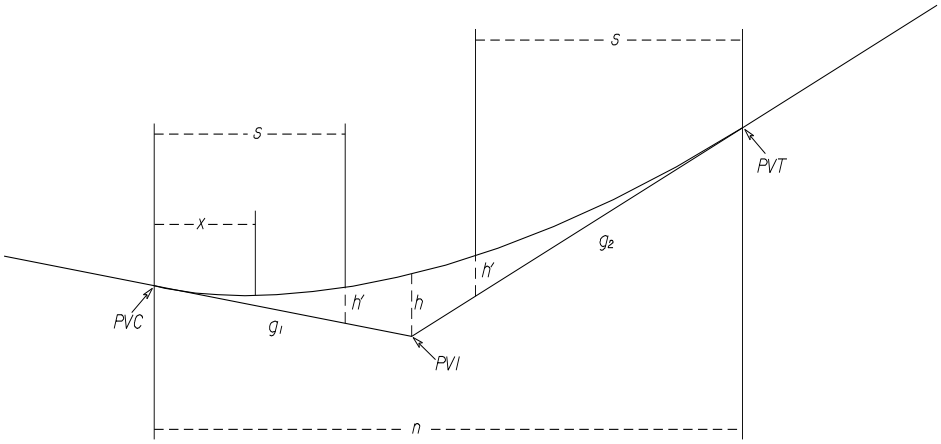
GIVEN	SOLUTION
$\Delta_L, \Delta_S, T_S, R_S$	$R_L = \frac{T_S \sin\Delta - R_S \operatorname{vers}\Delta + RS}{\operatorname{vers}\Delta_L}$
$\Delta_L, \Delta_S, T_L, R_L$	$R_S = \frac{T_L \sin\Delta - R_L \operatorname{vers}\Delta + R_L}{\operatorname{vers}\Delta_S}$
$\Delta_L, \Delta_S, R_L, R_S$	$T_L = \frac{R_L \operatorname{vers}\Delta - (R_L - R_S)\operatorname{vers}\Delta_S}{\sin\Delta}$
$\Delta_L, \Delta_S, T_S, R_L$	$R_S = \frac{T_S \sin\Delta - R_L \operatorname{vers}\Delta_L}{\operatorname{vers}\Delta - \operatorname{vers}\Delta_L}$
$\Delta_L, \Delta_S, T_L, R_S$	$R_L = \frac{R_S \operatorname{vers}\Delta_S - T_L \sin\Delta}{\operatorname{vers}\Delta_S - \operatorname{vers}\Delta}$
$\Delta_L, \Delta_S, T_L, T_S$	$R_S = \frac{T_S \sin\Delta - \tan 1/2\Delta_L (T_L + T_S \cos\Delta)}{\operatorname{vers}\Delta - \sin\Delta \tan 1/2\Delta_L}$
Δ, T_L, T_S, R_S	$\tan 1/2\Delta_L = \frac{T_S \sin\Delta - R_S \operatorname{vers}\Delta}{T_L + T_S \cos\Delta - R_S \sin\Delta}$
Δ, T_L, T_S, R_L	$\tan 1/2\Delta_S = \frac{R_L \operatorname{vers}\Delta - T_L \sin\Delta}{R_L \sin\Delta - T_L \cos\Delta - T_S}$
Δ, T_S, R_L, R_S	$\cos\Delta_L = \frac{R_L - T_S \sin\Delta - R_S \cos\Delta}{R_L - R_S}$
Δ, T_L, R_L, R_S	$\operatorname{vers}\Delta_S = \frac{R_L \operatorname{vers}\Delta - T_L \sin\Delta}{R_L - R_S}$

LEGEND

- P.C. - Point of Curvature
- P.C.C. - Point of Compound Curvature
- P.T. - Point of Tangency
- R_L - Radius of Major Curve
- R_S - Radius of Minor Curve
- T_L - Long Tangent
- T_S - Short Tangent
- Δ - Total Deflection Angle of the Compound Curve = $\Delta_L + \Delta_S$
- Δ_L - Deflection Angle of Major Curve
- Δ_S - Deflection Angle of Minor Curve

VERTICAL CURVE FORMULAE

VERTICAL CURVE FORMULAE



h = center orientation
h' = correction at any point on curve
n = length of vertical curve in feet
g_1 = grade in expressed as feet per foot. For example, 2% would be expressed as 0.02.
g_2 = grade out expressed the same as grade in.
s = horizontal distance, on curve measured from nearest end of curve, in feet.
x = horizontal distance, in feet, messurse from PVC to point on curve
y = elevation of any point on vertical curve in feet
y° = elevation at PVC, in feet

1) $h = \frac{n}{8}(g_1 - g_2)$

2) $h' = h\left(\frac{2s}{n}\right)^2$

Elevation Equation for any point on curve: $y = y^\circ + g(x) + \left(\frac{g_2 - g_1}{2n}\right)(x)^2$

Equation for Low or High Point of Curve: $x = \left(\frac{-gn}{g_2 - g_1}\right)$

SPIRAL CURVE FORMULAE

In order to approximate the path a vehicle makes when entering or leaving a circular horizontal curve, a spiral transition curve will be provided for horizontal curves with a radius less than or equal to 850 meters, except for interchange ramps and loops.

The spiral to be used is known as the Talbot Transition Spiral and has the following characteristics:

1. - The radius of the spiral at any point is inversely proportional to its length. The radius at the TS (beginning of the spiral) is infinite and at the SC (end of the spiral) is equal to the radius of the circular curve R.

    R radius of the circular curve
    r radius at the distance L_x from TS
    LS length of spiral

    $R \div r = L_x \div LS$

2. - The central angle of a spiral curve is exactly 1/2 of a circular curve with the same radius and length.

    DE = central angle of spiral

    $DE = (28.6479 \times LS) \div R$

3. - Spiral angles are directly proportional to the squares of their lengths from the TS.

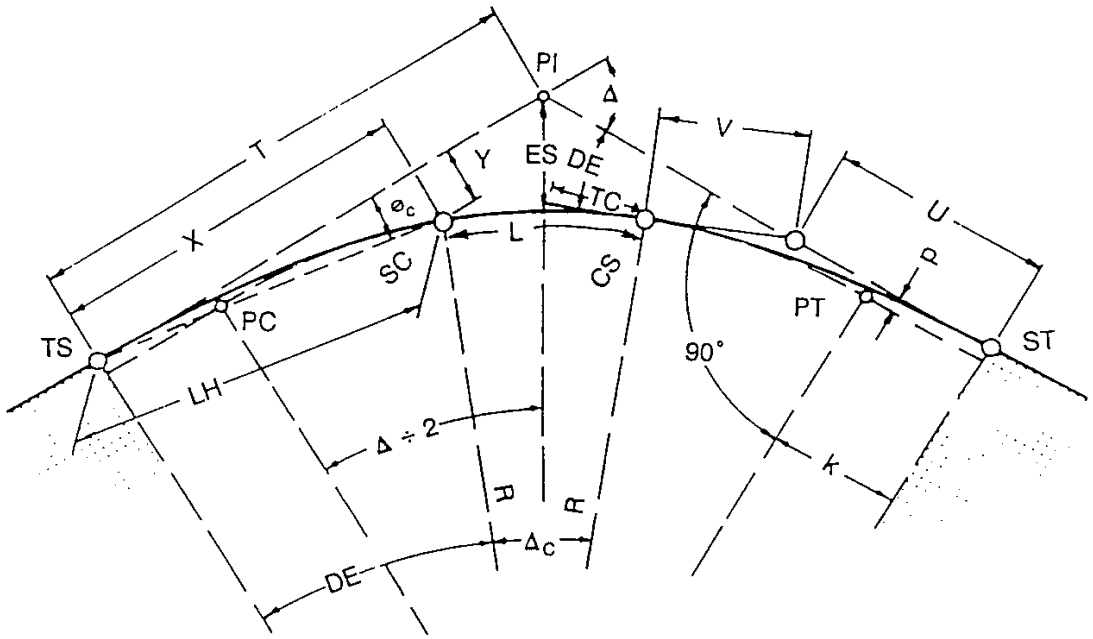
    Δ_L central angle for spiral for a length

    L_x from TS

    $\Delta_L = (L_x \div LS)^2 \times DE$

Formulas for computing spiral curve information is shown on the following page.

TRANSITION (SPIRAL) CURVE FORMULAE



LS =	Length of Spiral		V =	Short Tangent	
L =	Length of Circular Curve		X =	Tangent Distance for SC	
R =	Radius of Circular Curve		Y =	Tangent Offset of the SC	
TC =	Tangent of Circular Curve	k =	Simple Curve Coordinate (Abscissa)		
T =	Tangent Distance	p =	Simple Curve Coordinate (Ordinate)		
Δ =	Deflection Angle Between the Tangents		$\varnothing_C$ =	Deflection Angle of Spiral Curve	
DE =	Spiral Angle			TS =	Tangent to Spiral
Δ_C =	Central Angle Between the SC and CS			SC =	Spiral to Circular Curve
ES =	External Distance			CS =	Circular Curve to Spiral
LH =	Long Chord			ST =	Spiral to Tangent
U =	Long Tangent				

SPIRAL CURVE FORMULAS

DE =	$(28.6479 \times LS) \div R$	TC =	$R \times [\text{Tan} (\Delta_C \div 2)]$
Z =	$0.01745 \times DE$	Δ_C =	$\Delta - (2 \times DE)$
X =	$LS \times [1 - (Z^2 \div 10) + (Z^4 \div 216)]$	p =	$Y - [R \times (1 - \cos (DE)]$
Y =	$LS \times [(Z \div 3) - (Z^3 \div 42) + (Z^5 \div 1320)]$	k =	$X - [R \times (\sin (DE)]$
L =	$(R \times \Delta_C) \div 57.2958$		

TO CALCULATE T AND ES OF A SIMPLE CURVE WITH EQUAL SPIRALS

T = $[(R + p) \times \text{Tan} (\Delta \div 2)] + k$

ES = $[(R + p) \times \text{exsec} (\Delta \div 2)] + p$

ES = $[(R + p) \div \cos (\Delta \div 2)] - R$

TO CALCULATE THE TANGENT DISTANCES OF A SIMPLE CURVE WITH UNEQUAL SPIRALS

Ti_{in} = $[(R + P)_2 \div \sin \Delta] - [(R + p)_1 \times \cot \Delta] + k_1$

T_{out} $[(R + p)_1 \div \sin \Delta] - [(R + p)_2 \times \cot \Delta l + k$