b) $L = \dfrac{3.28 \times (0.278 \times 110)^3}{860} = 109.0\ m.$

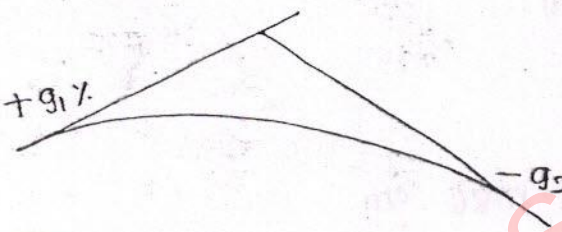
c) $L = 3.6 \times e = 3.6 \times 8.57 = 30.852\ m.$

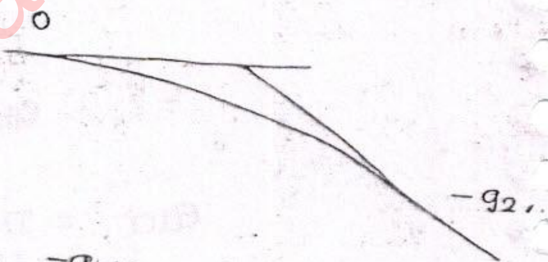
(Use) Length of transition curve $= 129.03\ m \simeq 130\ m$.

<u>Vertical curves</u> :

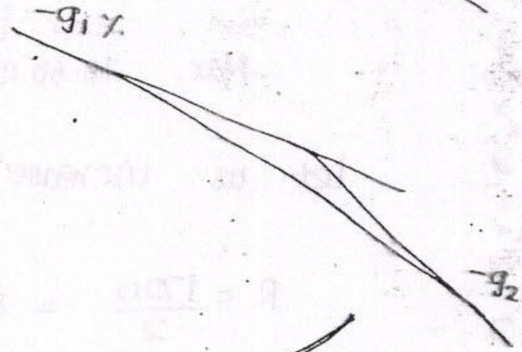
<u>Type of vertical curve</u> :

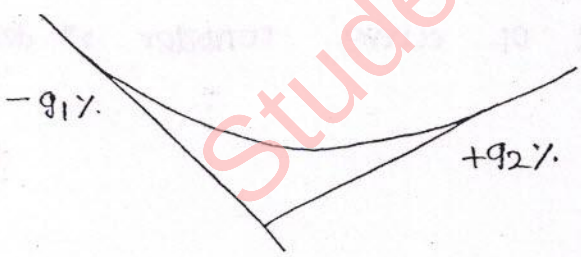
1. <u>summit curve</u> :

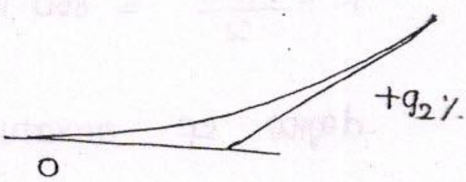


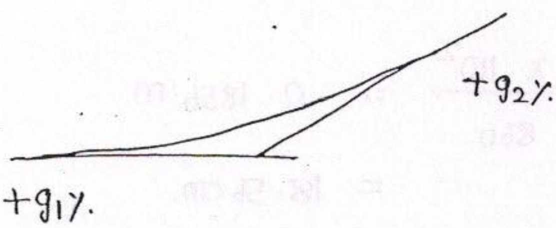


2. <u>Valley curve</u> :









#. If first gradient $= \pm g_1\%$

second gradient $= \pm g_2\%$.

Length of curve (valley curve):

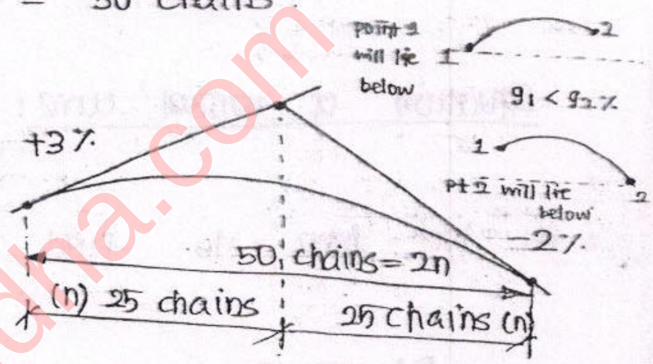
$$L = \frac{g_1 - g_2}{r\%} = 2n \text{ chains}$$

r = rate of change of gradient per chain length

Example:

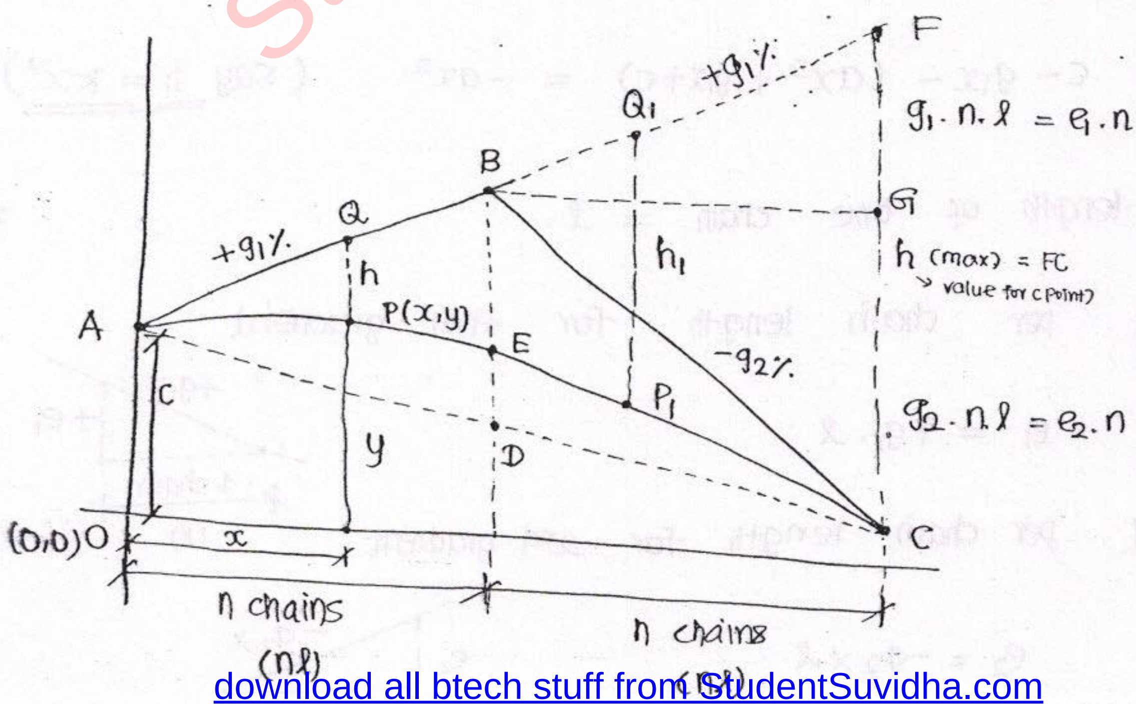
$g_1 = +3\%$, $g_2 = -2\%$, rate of change of gradient $= 0.10\%$

$$L = \frac{g_1 - g_2}{r\%} = \frac{3+2}{0.1} = 50 \text{ chains}$$



#. The total length of curve is exactly divided in two parts and provided on both sides of apex point. 'n' chains are provided on each side of point of intersection.

#. General case of a vertical curve:



General equation of a vertical curve (simple parabola are used)

$$y = ax^2 + bx + c \rightarrow ①$$

At $x = 0 \Rightarrow y = 0 + 0 + c \Rightarrow y = c$.

Slope equation $\frac{dy}{dx} = 2ax + b$

at $x = 0$, $dy/dx = g_1 = 2a.0 + b \Rightarrow b = g_1$.

Equation of vertical curve: $y = ax^2 + g_1 x + c$

#. We have to find R.L of diff. points on the curve:

RL of P = RL of Q − PQ (h).

RL of Q = $c + g_1 x$ | If all R.L are measured w.r.to X-axis.

h = R.L of Q − RL of P

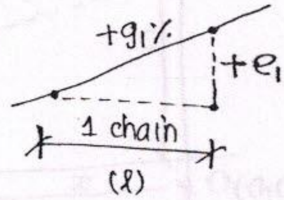
$= c - g_1 x - y$

$= c - g_1 x - (ax^2 + g_1 x + c) = -ax^2$ (say $\underline{h = kx^2}$).

If length of one chain $= l$.

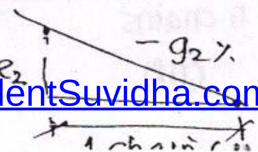
Rise per chain length for first gradient

$e_1 = +g_1 \cdot l$



Fall per chain length for 2nd gradient.

$e_2 = -g_2 \times l$



For last point 'c' of the curve,

$$h = \cancel{FG} = FC = g_1 n l - g_2 n.l.$$

$\boxed{h = ne_1 - n.e_2}$ General formula (use e_1/e_2 with sign).

$$h = kx^2$$

For last point C, value of $x = 2n$ chain.

$$n(e_1 - e_2) = k.(2n)^2 = k.4.n^2$$

$$k = \frac{n(e_1-e_2)}{4n^2} = \frac{e_1-e_2}{4n}$$

$$\boxed{h = \cancel{4}\ k.x^2 = \frac{e_1-e_2}{4n}.x^2}$$ $x \rightarrow$ no. of chains.

$\boxed{\text{RL of any point P} = \text{RL of Q} - h}$

#. Property of vertical curve:

$$\text{RL of E} = \frac{\text{RL of B} + \text{RL of D}}{2}$$

#. If RL of B is known.

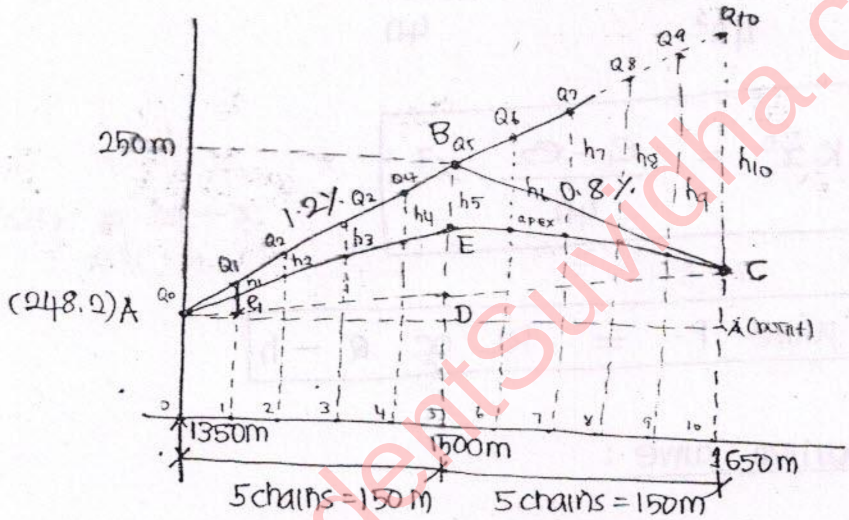
$$\text{RL of A} = \text{RL of B} - g_1 . n . l$$

$$\text{RL of C} = \text{RL of B} - g_2 . n . l$$

$$\text{RL of D} = \frac{\text{RL of A} + \text{RL of C}}{2}$$

$$\text{RL of E} = \frac{\text{RL of B} + \text{RL of D}}{2}$$

Q.1. A summit curve has a rising gradient of 1.2% and a falling gradient of 0.8%. calculate the length of summit curve if rate of change of gradient per chain length is 0.2%. Length of one chain is 30 m. If RL and chainage of intersection point is 250.0 m and 1500 m. calculate the RL and chainage of different points on the vertical curve. What is the highest point (apex point) of the curve.



e_1 & e_2 calculated based on the horizontal line

$g_1 = +1.2\%$, $g_2 = -0.8\%$

$$L = \frac{g_1 - g_2}{r\%} = \frac{1.2-(-0.8)}{0.2\%} = 10 \text{ chains} = 2n.$$

$n = 5$ chains

Length of one chain = 30 m (Given)

Chainage of A = 1500 − 150 = 1350 m.

Chainage of C = 1500 + 150 = 1650 m.

Chainage of B = 1500 m } Given.
RL of B = 250 m

$$RL \text{ of } A = RL \text{ of } B - g_1 \times 150$$

$$= 250 - \frac{1.2}{100} \times 150 = 248.2 \text{ m}.$$

With respect to 'B'. both points A & C are down. so $g_2 = 0.5$ and not $= -0.8$.

$$RL \text{ of } C = RL \text{ of } B - g_2 . n . l.$$

$$= 250 - \frac{0.8}{100} \times 150 = 248.8 \text{ m}$$

$$RL \text{ of } D = \frac{RL \text{ of } A + RL \text{ of } C}{2} = \frac{248.2 + 248.8}{2}$$

$$= 248.5 \text{ m}.$$

$$RL \text{ of } E = \frac{RL \text{ of } B + RL \text{ of } D}{2} = \frac{250 + 248.5}{2}$$

$$= 249.25 \text{ m}.$$

For RL of diff. points on the curve (for eg)

$$RL \text{ of } P_4 = RL \text{ of } (Q_4 - h_4)$$

<u>Value of h</u> :

$$h_1 = \frac{e_1 - e_2}{4n} . x^2$$

e_1 = rise per chain length $= g_1 . l = +\frac{1.2}{100} \times 30 = +0.36$ m.

e_2 = fall per chain length $= g_2 . l = -\frac{0.8}{100} \times 30 = (-)\ 0.24$ m.

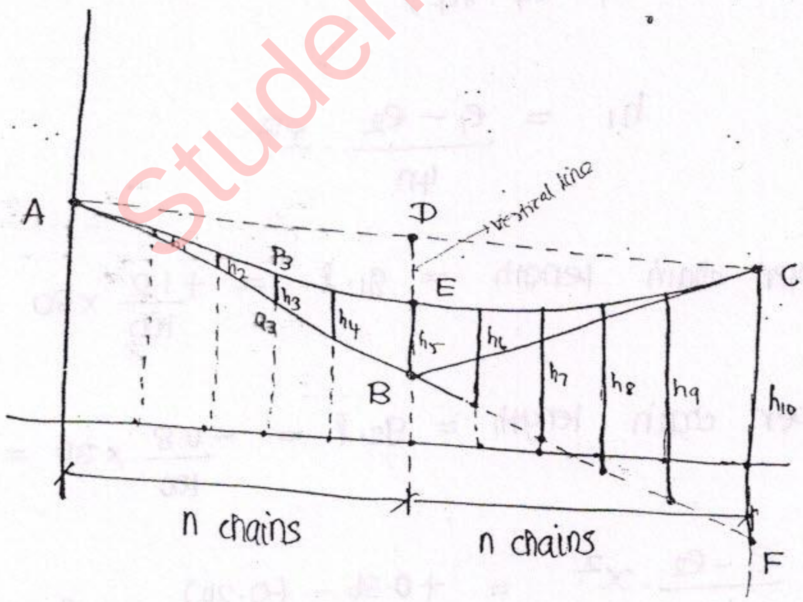
$$h = K . x^2 = \frac{e_1 - e_2}{4n} . x^2 = \frac{+0.36 - (-0.24)}{4 \times 5} \times x^2 = 0.03\, x^2.$$

where $x = 1, 2, 3, \ldots$ chains. $x \rightarrow$ no. of chains.

$$\boxed{RL \text{ of } P = RL \text{ of } Q - h}$$

Points	chainage	RL of Q	h	RL of P
0-A	1350	248.20	0.08	248.2
1	1380	248.56	0.03	248.53
2	1410	248.92	0.12	248.8
3	1440	249.28	0.27	249.01
4	1470	249.64	0.48	249.16
B-5-E	1500	250.00	0.75	249.25
6	1530	250.36	1.08	249.28 → apex point
7	1560	250.72	1.47	249.25
8	1590	251.08	1.92	249.16
9	1620	251.44	2.43	249.01
10-C	1650	251.80	3	248.8

Incase of valley curve :

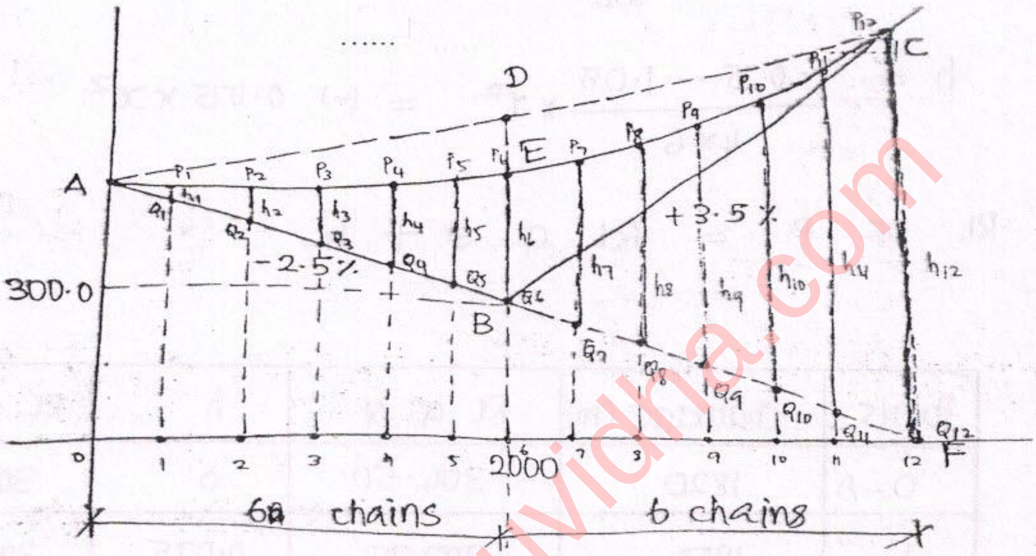


$$RL \text{ of } P_3 = RL \text{ of } Q_3 + h_3$$

$$h_3 = k.x^2 = \frac{e_1 - e_2}{4n} \times x^2.$$

Q.2. A valley curve is formed by a falling gradient of 2.5% and rising gradient of 3.5%. rate of change of gradient per chain length is 0.5%. RL & chainage of intersection points are 300 m and 2000 m. Calculate RL of diff. points on the curve. Find out apex point also.

ES 1988 8.0
ES 1995 6.0



$$L = \frac{g_1 - g_2}{r\%} = 2n = \frac{-2.5-3.5}{0.5} = 12 = 2n$$

$n = 6$ chains. (Assume length of one chain = 30 m).

$nl = 6 \times 30 = 180$ m.

Chainage of A $= 2000 - (6\times30) = 1820$ m

Chainage of C $= 2000 + (6*30) = 2180$ m.

RL of A = RL of B $- g_1 \times nl$

$= 300 + \frac{2.5}{100} \times 180 = 304.5$ m.

RL of C = RL of B + $g_2 \times nl$ $= 300 + \frac{3.5}{100} \times 180$

$= 306.3$ m

RL of D $= \frac{\text{RL of A} + \text{RL of C}}{2} = \frac{304.5 + 306.3}{2} = 305.4$ m

$$RL \text{ of } E = \frac{RL \text{ of } B + RL \text{ of } D}{2} = \frac{300 + 305.4}{2} = 302.7\,m$$

$$h = \frac{e_1 - e_2}{4n} \times x^2 \Rightarrow x \to \text{no. of chains.}$$

$$e_1 = g_1 \times l = \frac{(-)2.5}{100} \times 30 = (-)0.75\ m$$

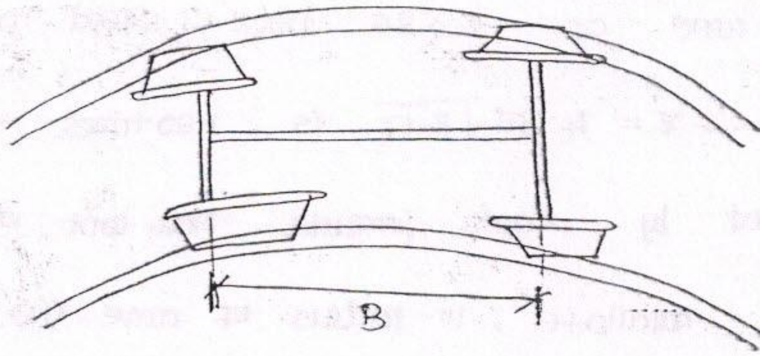
$$e_2 = g_2 \times l = (+)\frac{3.5}{100} \times 30 = 1.05\ m$$

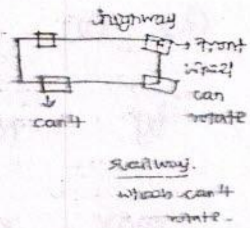
$$h = \frac{-0.75 - 1.05}{4 \times 6} \times x^2 = (-)\ 0.075 \times x^2$$

RL of P = RL of Q + h.

Points	Chainage (m)	RL of Q	h	RL of P
0–A	1820	304.50	0	304.50
1	1850	303.75	0.075	303.825
2	1880	303.00	0.30	303.30
3	1910	302.25	0.675	302.925
4	1940	301.50	1.20	302.70
5	1970	300.75	1.875	302.625 → apex point
E–6–B	2000	300.00	2.70	302.70
7	2030	299.25	3.675	302.925
8	2060	298.50	4.80	303.30
9	2090	297.75	6.075	303.825
10	2120	297.00	7.50	304.50
11	2150	296.25	9.075	305.325
12–C	2180	295.50	10.80	306.30

#. Extra widening on curve :





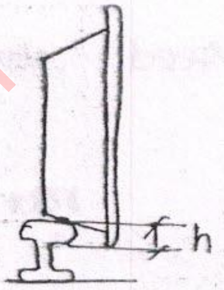
On curve, some extra widening is required

$$\boxed{E_W = \frac{13(B+L)^2}{R}} \longrightarrow ①$$

B → meter

L → meter

E_W → (cm). R → meter



Here B = width of wheel base in meter

= 6.0 m in B.G track

= 4.88 m in M.G track

L = lap of flange in meter = $0.02\sqrt{h^2 + Dh}$

where D = Dia. of wheel in meter (centi) ⇒ cm

h = depth of flange below top of the rail surface. = (cm).

L → metre

Q.1. For a B.G track, wheel base length is 6.0 m. Dia. of wheel is 1.2 m. calculate extra widening required if depth of flange below rail surface is 3.10 cm. Radius of curve is 430 m.

$$L = 0.02\sqrt{h^2 + Dh} = 0.02\sqrt{3.10^2 + 120 \times 3.10}$$

$$= 0.39 \text{ m}$$

$$E_W = \frac{13\,(6.0+0.39)^2}{R} = 1.23 \text{ cm.}$$

430

Equilibrium speed = 80 kmph

Q.2. On a transition curve of a BG track. Speed calculated by Martin's formula, $V = 4.35\sqrt{R-67}$ is 1.30 times the max. speed calculated by can't formula. Max. cant deficiency allowed is 10 cm. calculate, (i) radius of curve (ii) max. speed allowed (iii) Actual cant provided (iv) length of T.C

$$4.35 \times \sqrt{R-67} = \sqrt{\frac{127 \times R \times e_{th}}{1.676}} \times 1.3$$

$$e_{th} = e_{act} + D$$

$$= 16.5 + 10 = 26.5\text{cm. (WRONG).}$$

Solution:

$$e_{th} = \frac{GV^2}{127R} + 0.10 \text{ (meter).}$$

$$e_{th} = \frac{1.676 \times 80^2}{127 \times R} + 0.10 = \frac{84.46}{R} + 0.1 = \frac{G.V_{max}^2}{127.R}$$

$$V_{max} = \sqrt{\frac{127 \times R \times e_{th}}{G}} = \sqrt{\frac{127 \times R \times}{1.676}\left(\frac{84.46}{R} + 0.1\right)}$$

$$4.35\sqrt{R-67} = \sqrt{\frac{127 \times R}{1.676}\left(\frac{84.46}{R} + 0.1\right)} \times 1.3$$

$$\sqrt{R-67} = \frac{1.3}{4.35} \times 8.705\sqrt{84.46 + 0.1R}$$

$$R - 67 = 67.77\,(84.46 + 0.1R) \Rightarrow R = 1977.7\text{m}$$

say $R = 1978$ m.

2. <u>max. speed allowed</u> :

$e_{th} = \frac{84.46}{R} + 0.1$

(cant formula) (bcz value less than (martin's formula)

$= 0.1426$ m

$$V_{max} = \sqrt{\frac{127 \times 1978 \times 0.1426}{1.676}} = 146.25 \text{ kmph}.$$

$\simeq$ (say) 146 kmph.

3. <u>Actual cant provided</u>,

$$e_{act} = \frac{G V_{av}^2}{127 R} = \frac{1.676 \times 80^2}{127 \times 1978}$$

$= 0.0427$ m

$= 4.27$ cm.

4. <u>Length of transition curve</u> :

$$L = 4.4\sqrt{R} = 4.4\sqrt{1978} = 195.688 \text{ m}.$$

$$L = 3.28 \frac{(0.278 \times 146)^3}{1978} = 110.876 \text{ m}.$$

$$L = 3.6 \times e = 3.6 \times 4.27 = 15.372 \text{ m}.$$

Length of transition curve $= 195.688$ m $\simeq L = 195$ m.

POINTS AND CROSSINGS :

(weak points).

<u>Turnout</u> : Turnout is a combination of point & crossing, to divert the train from one track to another.

These points and crossings are subjected to heavy wear and tear due to heavy impact load, thus need a lot