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)

$$= 0.1426 \text{ m}$$

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

$$\simeq \text{(say)}\ 146 \text{ kmph}.$$

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

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

$$= 0.0427 \text{ m}$$

$$= 4.27 \text{ cm}.$$

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

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

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

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

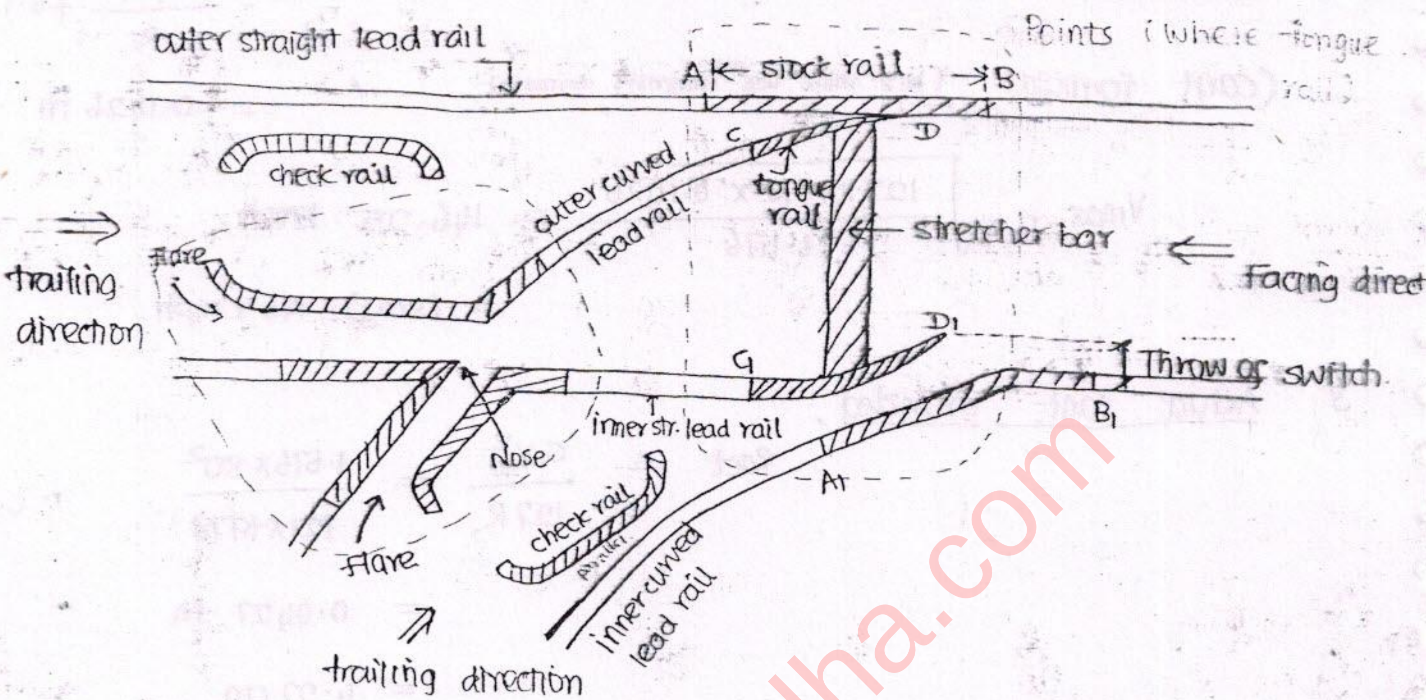
Length of transition curve $= 195.688$ m $\simeq L = 195$ m.

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 of maintenance. so very high strength steel (high manganese steel) are used for points & crossings.



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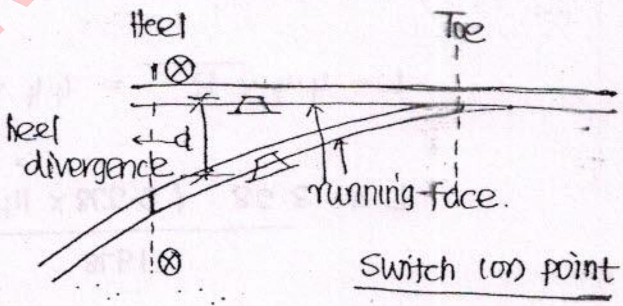
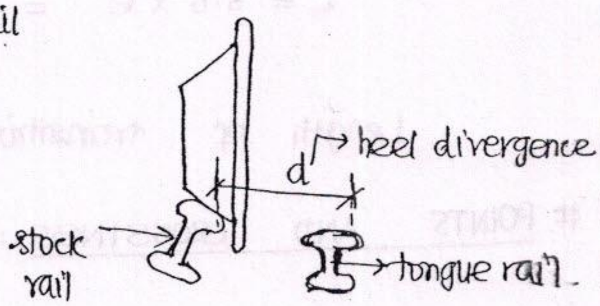
Points :

1. Heel divergence :



* The distance between running faces of stock rail and tongue rail of the switch at heel.

* denoted by 'd'.



In India, for BG = 13.7 to 13.3 cm

for MG = 12.7 to 12.1 cm.

for NG = 9.8 cm

2. Flangeway clearance :

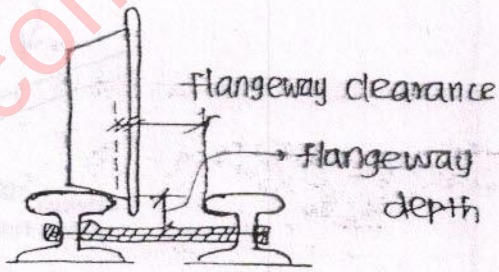
The distance between adjacent faces of stock rail and tongue rail at heel of the switch is called flangeway clearance.

value for 1 in 12 crossing = 6.3 cm

1 in 8½ crossing = 6.6 cm.

3. Flangeway depth: The depth of heel block measured from top of the rail surface is called flangeway depth.

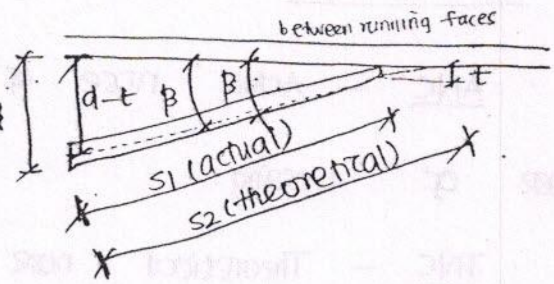
4. Throw of switch:



The distance by which the toe of the switch moves sideways is called throw of switch.

for B.G = 9.5 cm, M.G/N.G = 8.9 cm.

5. Switch angle:



β = switch angle

s_1 = actual length of tongue rail

s_2 = theoretical length of tongue rail

$$\sin\beta = \frac{d}{s_2} = \frac{d-t}{s_1}$$

switch angle:

$$\beta = \sin^{-1}\left(\frac{d}{s_2}\right) = \sin^{-1}\left(\frac{d-t}{s_1}\right).$$

Q.1. What will be the angle of switch and heel divergence if theoretical length of tongue rail is 5.15 m and actual length of tongue rail is 4.82 m. Thickness of tongue rail

at toe =

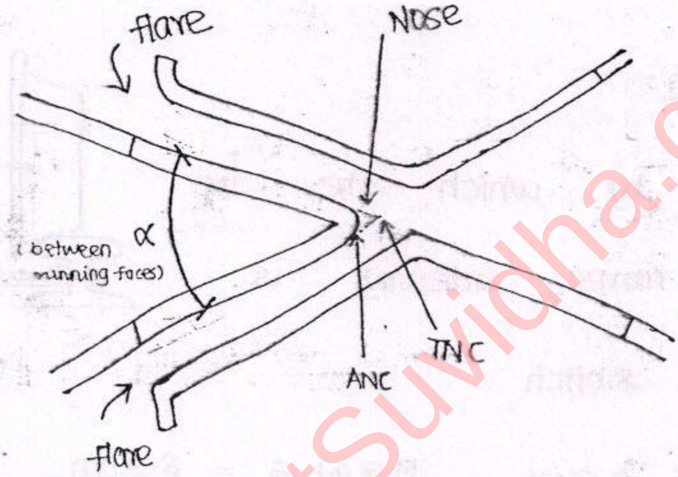
$S_2 = 5.15m$, $S_1 = 4.82m$, $t = 0.60$ cm

$$\frac{d}{S_2} = \frac{d-t}{S_1} \Rightarrow \frac{d}{515} = \frac{d-0.6}{482} \Rightarrow d = 9.36 \text{ cm}$$

Switch angle:

$$\beta = \sin^{-1}\left(\frac{d}{S_2}\right) = \sin^{-1}\left(\frac{9.36}{515}\right) = 1°2'30.48''$$

#. crossing :



1. ANC & TNC :

ANC – Actual nose of crossing due to blunt face at th nose of crossing.

TNC – Theoretical nose of crossing which thickness is considered zero at the nose.

2. Angle of crossing and number of crossing :

#. Angle of crossing :

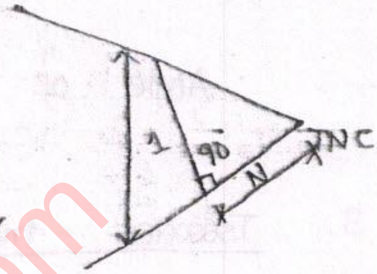
Angle made between the two running faces of crossing as shown in fig (say angle α).

Number of crossing :

It is the ratio of spread of two legs of crossing to distance of rail from TNC.

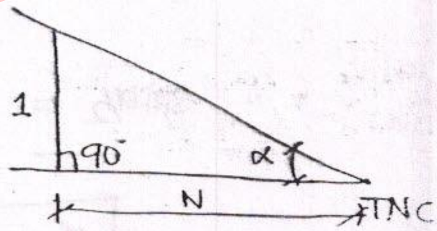
There are different methods to show number of crossing.

1. Cole's method : (used for Indian Railway)



Also called right angle triangle method.

As shown in fig. distance required (N) for 1m spread measured at right angle.



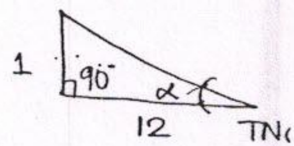
$$\tan\alpha = \frac{1}{N} \Rightarrow \boxed{\cot\alpha = N}$$

$$\alpha = \tan^{-1}\left(\frac{1}{N}\right) = \cot^{-1}(N)$$

α = angle of crossing. 1 in N = number of crossing

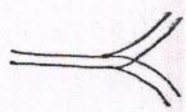
For example :

If number of crossing is 1 in 12



$$\tan\alpha = \frac{1}{12} \Rightarrow \alpha = \tan^{-1}(1/12) = 4°45'49.11''$$

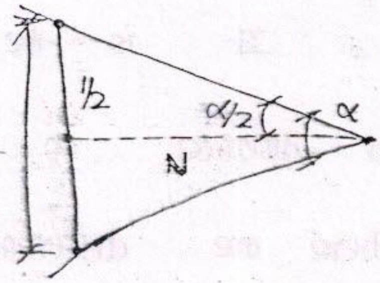
Different number of crossing :



No. of crossing	Angle of crossing	use
* 1 in 6	9° 27' 44"	used for symmetrical splits
* 1 in 8½	6° 42' 35"	used on station yards where space is restricted.
* 1 in 12	4° 45' 49"	used on station yard of main lines.
* 1 in 16	3° 34' 35"	used on main lines of BG tra

2. <u>Centre line method</u> :

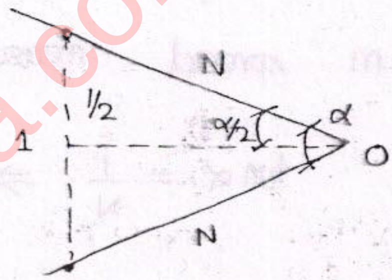
$$\tan \alpha/2 = \frac{1/2}{N} = \frac{1}{2N}$$



$$\boxed{\cot \alpha/2 = 2N}$$

Angle of crossing , $\boxed{\alpha = 2\cot^{-1}(2N)} = 2\tan^{-1}\left(\frac{1}{2N}\right)$

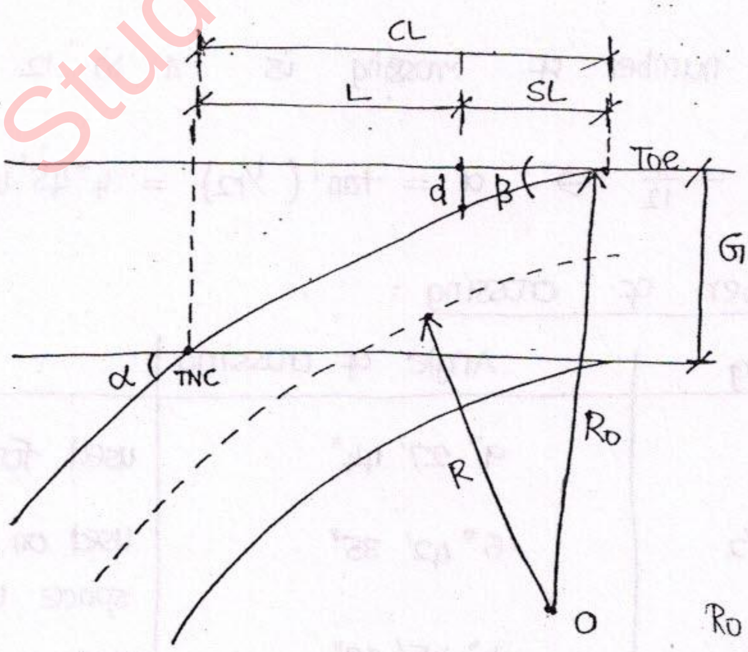
3. <u>Isosceles triangle method</u> :



$$\sin \alpha/2 = \frac{1}{2N} \Rightarrow \operatorname{cosec} \alpha/2 = 2N$$

$$\boxed{\alpha = 2\operatorname{cosec}^{-1}(2N)}$$

<u>Design calculations of a turnout</u> :



SL – switch lead

CL – curve lead

L – Lead

$R_0 \rightarrow$ outer radius

$R \rightarrow$ central radius

Imp points of a turnout :

1. curve lead : Distance measured parallel to stock rail from toe of switch to TNC (CL).

2. Switch lead : (SL) Distance b/w toe of switch and heel of switch measured along straight stock rail.

3. Lead (L) : Distance from heel of switch to TNC as shown in figure.

$$\boxed{CL = SL + L} \rightarrow (1)$$

4. Angle of crossing (α) (or) no. of crossing (1 in N) :

$$N = \cot\alpha$$

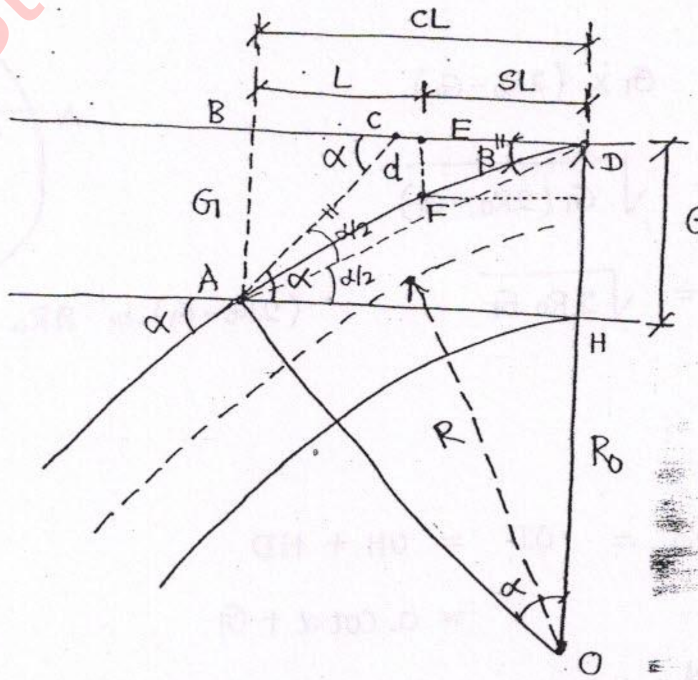
5. Angle of switch (β) (6) heel divergence (d) (8) Gauge (G).

7. Radius of curve : R – central radius.

R_0 – outer radius. $\boxed{R_0 = R + G/2}$

case 1 :

The complete length b/w TNC to toe of switch is curved :-



1. Curve lead (CL) :

ⓐ $CL = BC + CD$ $\qquad \tan\alpha = \frac{G}{BC}$

$BC = G\cot\alpha$

$CL = G\cot\alpha + G\,\mathrm{cosec}\,\alpha$

$\cot\alpha = N$

$CL = GN + G\sqrt{1+\cot^2\alpha}$

$\sin\alpha = \frac{G}{AC}$

$CL = GN + G\sqrt{1+N^2}$

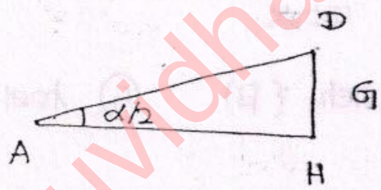
$AC = G\,\mathrm{cosec}\,\alpha$

$= CD$

$\simeq GN + GN = 2GN$

$\boxed{CL = 2GN} \longrightarrow ①$

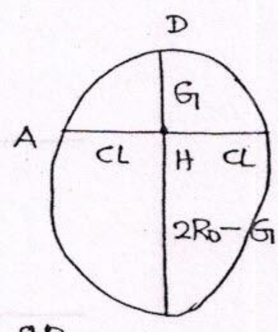
ⓑ



$\tan\alpha/2 = \frac{G}{AH} = \frac{G}{CL}$ $\qquad AH = CL.$

$AH = G\cot\alpha/2 \Rightarrow \boxed{CL = G\cot\alpha/2} \longrightarrow ②$.

ⓒ From property of circle :



$CL \times CL = G \times (2R_0 - G)$

$CL = \sqrt{G(2R_0 - G)}$

$CL = \sqrt{2R_0 \cdot G}$ $\qquad (2R_0 - G) \simeq 2R_0.$

2. Radius (R_0) :

$\tan\alpha = \frac{AH}{OH}$

$R_0 = OD = OH + HD$

$OH = AH\cot\alpha$

$= CL\cot\alpha + G$

$OH = CL\cot\alpha$

$\cot\alpha = N$ $\qquad = 2GN\,N + G$ $\qquad CL = 2GN.$

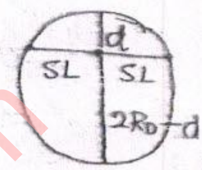
$$R_0 = G + 2GN^2$$

Indian Railway : $\boxed{R_0 = 1.5G + 2GN^2}$

$$R = R_0 - G/2$$

3. Switch lead (SL) :

Using property of circle ,



$$SL \times SL = d(2R_0 - d)$$

$$\boxed{SL = \sqrt{2R_0 \cdot d}}$$

4. Lead (L) :

$$L = CL - SL = 2GN - \sqrt{2 \cdot R_0 \cdot d}$$

$$= \sqrt{2R_0 \cdot G} - \sqrt{2 \cdot R_0 \cdot d}$$

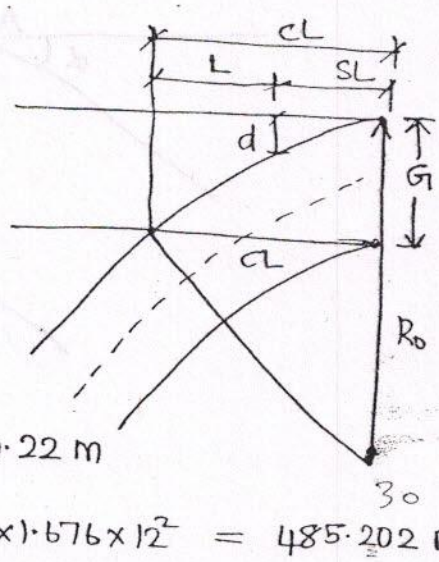
Q.1. Calculate the necessary elements to setout a turnout taking from a straight BG track of no. of crossing 1 in 12. heel divergence is 12 cm. The curve is starting from the toe of switch and ends at TNC. calculate (i) CL (ii) Ro (iii) SL (iv) lead (v) R.

$d = 12$ cm.

1 in 12 crossing

$N = \cot\alpha = 12$

$\alpha = \cot^{-1}(12) = 4°45'49.11''$



(i) $CL = 2 \times G \times N = 2 \times 1.676 \times 12 = 40.22$ m

(ii) $R_0 = 1.5G + 2GN^2 = 1.5 \times 1.676 + 2 \times 1.676 \times 12^2 = 485.202$ m.

(iii) switch lead (SL) $= \sqrt{2 . R_0 . d}$

$= \sqrt{2 \times 485.2 \times 0.12} = 10.79$ m.

metre

(iv) Lead (L) $= CL - SL$

$= 40.22 - 10.79 = 29.43$ m.

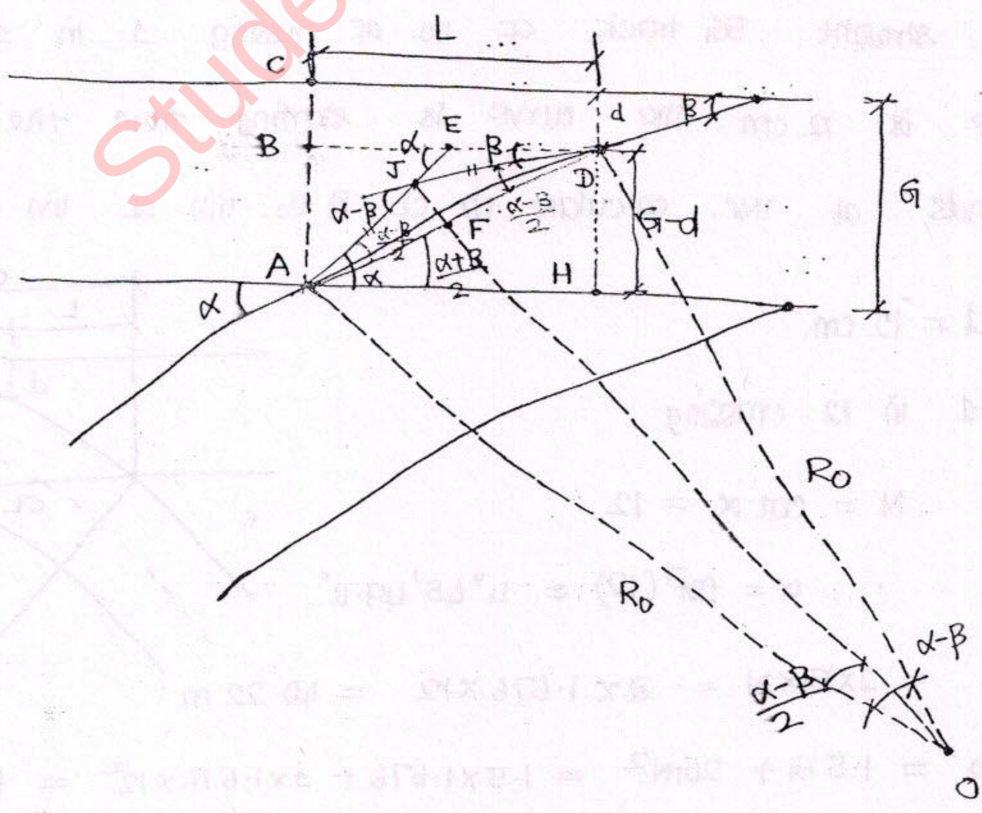
(v) central radius (R) $= R_0 - G/2$

$= 485.2 - 1.676/2 = 484.36$ m.

<u>case 2</u> :

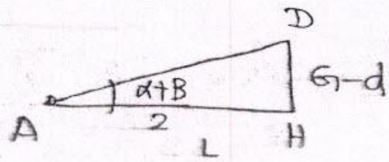
The curve starts from heel of the switch and ends at TNC.

In this method we need only two values. (i) Lead (L) (ii) Radius (R_0)



1. Lead (L) : In triangle ADH

$$\tan\left(\frac{\alpha+\beta}{2}\right) = \frac{G-d}{L}$$



$$\boxed{L = (G-d)\ \cot\left(\frac{\alpha+\beta}{2}\right)} \longrightarrow (1)$$

2. Radius (R_0) :

In triangle ADH

$$\sin\left(\frac{\alpha+\beta}{2}\right) = \frac{G-d}{AD}$$

In triangle AFO,

$$\sin\left(\frac{\alpha-\beta}{2}\right) = \frac{AF}{R_0} = \frac{AD}{2R_0}$$

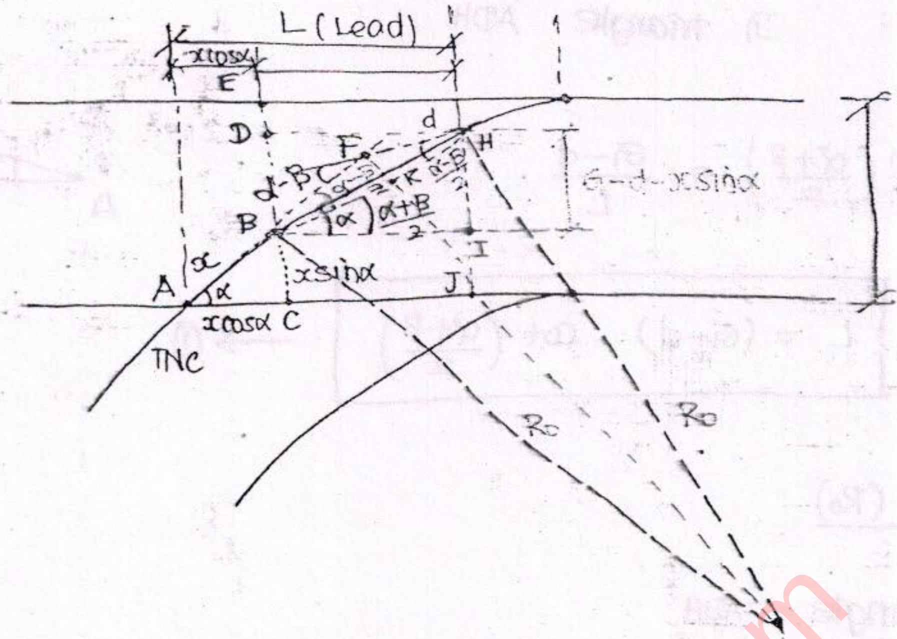
$$AD = \frac{G-d}{\sin\left(\frac{\alpha+\beta}{2}\right)}$$

$$R_0 = \frac{AD}{2\sin\left(\frac{\alpha-\beta}{2}\right)} = \frac{G-d}{2\sin\left(\frac{\alpha+\beta}{2}\right).\sin\left(\frac{\alpha-\beta}{2}\right)}$$

$$\boxed{R_0 = \frac{G-d}{\cos\beta - \cos\alpha}} \rightarrow (2) \qquad R_0 = \frac{G-d}{\cos\beta - \cos\alpha}$$

$\cos(A-B) - \cos(A+B)$

Case 3 : In this case, a straight portion is provided just before TNC also. The curve will start from heel of switch and ends at starting point of straight portion before TNC.

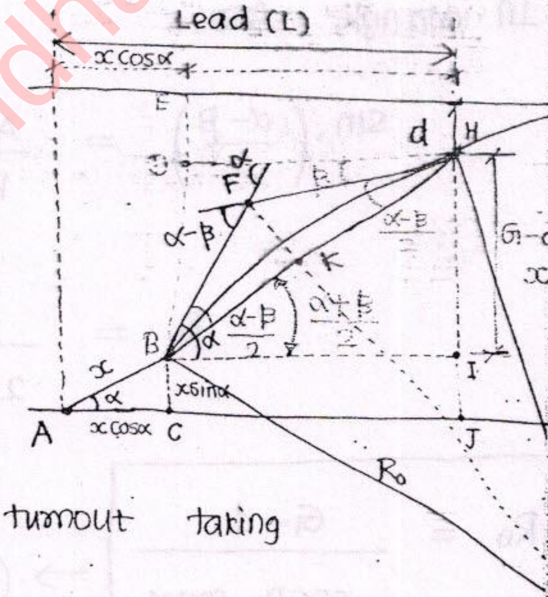


1. Lead (L) :

$$L = x\cos\alpha + \cancel{(G-d)}\,(G-d-x\sin\alpha)\ \cot\left(\frac{\alpha+\beta}{2}\right)$$

2. Radius (R_0) :

$$\boxed{R_0 = \frac{G-d-x\sin\alpha}{\cos\beta - \cos\alpha}}$$



ES1994. 8.b) Calculate the necessary elements to setout a 1 in 8½ turnout taking from a straight B.G track with its curve starting from the heel of the switch and ending at a distance of 864 mm from TNC. Given that heel divergence = 136 mm, switch angle = 1°34'27". Make a free hand sketch.

Number of crossing = 1 in 8.5

$$N = \cot\alpha \Rightarrow \alpha = \cot^{-1}(8.5) = 6°42'35.41"$$

switch angle (β) Given $= 1°34'27''$.

$G = 1.676$ m, $x = 864$ mm $= 0.864$ m. $d = 0.136$ m.

$$\text{Lead } (L) = x\cos\alpha + (G - d - x\sin\alpha)\cot\left(\frac{\alpha+\beta}{2}\right).$$

$$\text{Radius } (R_0) = \frac{G - d - x\sin\alpha}{\cos\beta - \cos\alpha}$$

$$\text{Lead } (L) = 0.864\cos 6°42'35.41'' + (1.676 - 0.136 - 0.864\sin 6°42'35.41'')\cot\left(\frac{\alpha+\beta}{2}\right)$$

$$= 0.858 + \left(1.439\cot\left(\frac{6°42'35.41'' + 1°34'27''}{2}\right)\right)$$

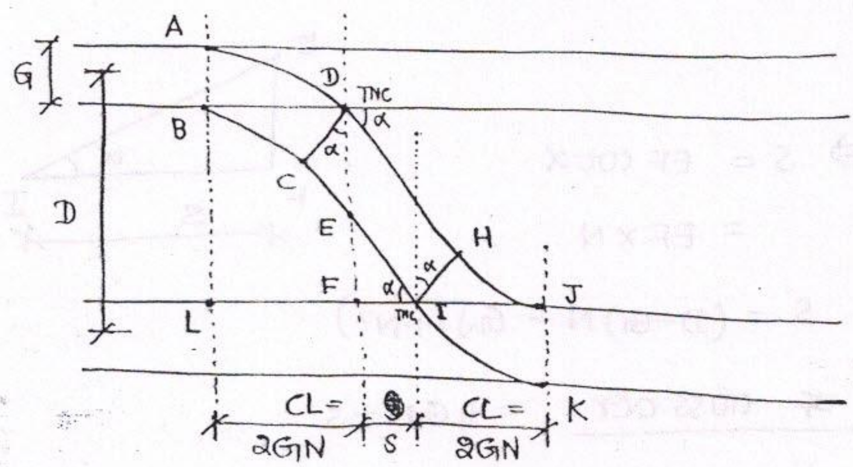
$$= 20.389 \text{ m}.$$

$$\text{Radius } (R_0) = \frac{1.439}{\cos\beta - \cos\alpha} = 222.35 \text{ m}.$$

Cross over :

There are three types.

1. With a straight portion in between the two turnouts :



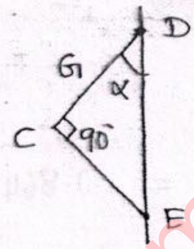
G = Gauge , D = c/c distance b/w two tracks .

overall length of cross over :

$$= CL + S + CL = 2GN + S + 2GN$$

$$= 4GN + S .$$

In triangle CDE



$$\cos\alpha = \frac{G}{DE}$$

$$DE = G\sec\alpha$$

Value of EF :

$$EF = DF - DE$$

$$= (D-G) - G\sec\alpha$$

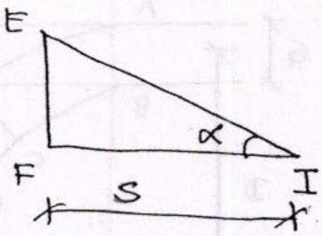
$$= (D-G) - G\sqrt{1+\tan^2\alpha}$$

$$= (D-G) - G\sqrt{1+\frac{1}{\cot^2\alpha}} \qquad \cot\alpha = N$$

$$= (D-G) - G\sqrt{1+\frac{1}{N^2}}$$

$$EF = \left[(D-G) - \frac{G\sqrt{1+N^2}}{N}\right]$$

In triangle EFI



$$\tan\alpha = \frac{EF}{S} \Rightarrow S = EF\cot\alpha$$

$$= EF \times N$$

$$S = (D-G)N - G\sqrt{1+N^2})$$

Overall length of cross over : $= 4GN + S$

$$= 4GN + (D-G)N - G\sqrt{1+N^2}$$

Q.1. A crossover is formed b/w two BG track using turnouts of 1 in 16 at both ends. The intermediate portion b/w turnout is straight. Calculate overall length of crossover if c/c distance b/w tracks = 6.5m.

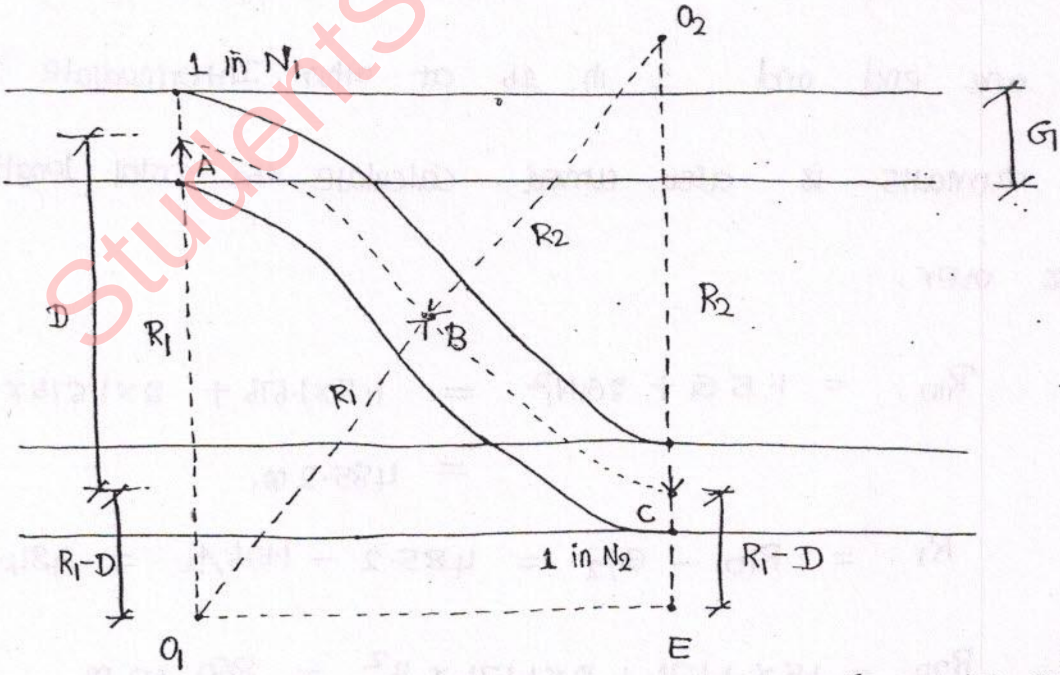
overall length of cross over = ~~4GN+ (G-D)~~

$$= 4GN + (D-G)N - \sqrt{1+N^2}\cdot G.$$

$$= 4\times1.676\times16 + (6.5-1.676)16 - \sqrt{1+16^2}\cdot 1.676$$

$$= 157.58\,m.$$

<u>case(ii)</u> <u>If intermediate portion b/w turnouts is also curved.</u>



$O_1 \to$ centre of one (1st) curve

$O_2 \to$ centre of 2nd curve.

$R_1 \to$ central radius of 1st curve

$R_2 \to$ central radius of 2nd curve.

$R_{010} \to$ outer radius of 1st curve

$R_{020} \to$ outer radius of 2nd curve.

$$R_{10} = 1.5G + 2GN_1^2$$

$$R_1 = R_{10} - G/2$$

$R_{20} = 1.5G + 2GN_2^2$

$R_2 = R_{20} - G/2$

In triangle O_1O_2E , $O_1O_2 = R_1 + R_2$

$O_2E = R_2 + (R_1 - D)$

$= R_1 + R_2 - D$.

$a^2 - b^2 = (a+b)(a-b)$

$= (R_1+R_2+R_1+R_2-D)(R_1+R_2-R_1-R_2+D)$

$= (2R_1+2R_2-D) . D$

Value of overall length of cross over

$O_1E = \sqrt{O_1O_2^2 - O_2E^2}$

$l = \sqrt{(R_1+R_2)^2 - (R_1+R_2-D)^2} = \sqrt{(2R_1+2R_2-D).D}$

Q.2. A cross over is formed b/w two B.G tracks at a distance of 8m c/c by joining two turnouts of 1 in 12 at one end and 1 in 16 at other. Intermediate portion b/w the turnouts is also curved. Calculate the total length of the cross over.

$R_{10} = 1.5G + 2GN_1^2 = 1.5 \times 1.676 + 2 \times 1.676 \times 12^2$

$= 485.2$ m.

$R_1 = R_{10} - G/2 = 485.2 - 1.676/2 = 484.36$ m.

$R_{20} = 1.5 \times 1.676 + 2 \times 1.676 \times 16^2 = 860.62$ m.

$R_2 = 860.62 - 1.676/2 = 859.78$ m.

In $\Delta O_1O_2E \Rightarrow O_1O_2 = R_1 + R_2 = 1344.1$ m.

$O_2E = R_1 + R_2 - D = 1336.1$

overall length of cross over, $l = \sqrt{1344.1^2 - 1336.14^2}$

$l = 145.99\,m$.

<u>case 3</u>: <u>If no. of crossing is same at two ends</u>:

$R_1 = R_2 = R$

Overall length of cross over, $l = \sqrt{O_1O_2^2 - O_2E^2}$

$= \sqrt{(R_1+R_2)^2 - (R_1+R_2-D)^2}$

$= \sqrt{(2R)^2 - (2R-D)^2}$

$a^2 - b^2 = (a+b)(a-b)$

$= (2R+2R-D)(2R-2R+D)$

$= (4R-D).D.$

$$\boxed{l = \sqrt{(4R-D).D}}$$

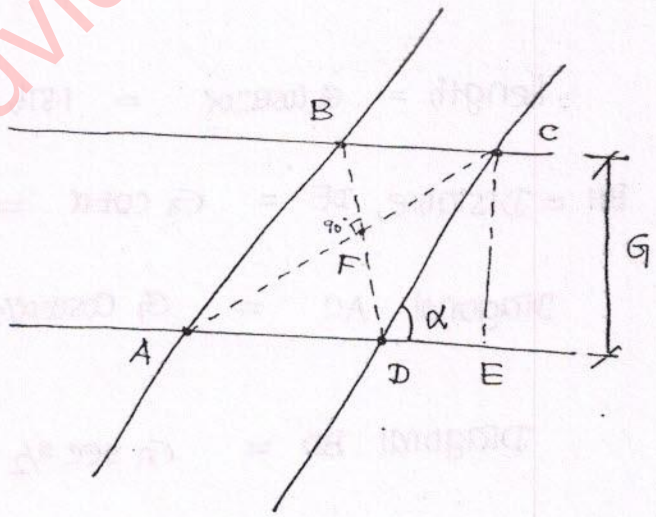
<u>case 4</u> : <u>Diamond crossing</u> :

If crossing number is given

$= 1$ in N

$\cot\alpha = N$

$\alpha = \cot^{-1}(N) = \tan^{-1}\left(\frac{1}{N}\right)$



<u>components</u>:

1. <u>Length</u> $AB = BC = CD = DA = G\,\mathrm{cosec}\,\alpha \rightarrow (1)$ $\qquad \sin\alpha = \frac{G}{CD}$

$CD = G\,\mathrm{cosec}\,\alpha.$

2. <u>Distance DE</u> $\Rightarrow$ $\tan\alpha = \frac{G}{DE}$

$$\boxed{DE = G\cot\alpha} \rightarrow (2)$$

3. <u>Diagonal AC</u>

$\sin\alpha/2 = \frac{G}{AC} \Rightarrow \boxed{AC = G\,\mathrm{cosec}\,\alpha/2} \rightarrow (3)$

4. Diagonal BD

In ΔAFD, $\tan\frac{\alpha}{2} = \frac{DF}{AF} \Rightarrow DF = AF \cdot \tan\alpha/2$

$$DF = \frac{AC}{2}\tan\alpha/2$$

$$\frac{BD}{2} = \frac{G \cdot \operatorname{cosec}\alpha/2}{2} \cdot \tan\alpha/2$$

$$\boxed{BD = G\sec\alpha/2} \longrightarrow (4)$$

Q.7.b ES1997. Design a diamond crossing b/w two B.G tracks crossing each at an angle of 1 in 10.

$$N = 10 = \cot\alpha \Rightarrow \alpha = \cot^{-1}(10) = 5^\circ 42' 38.14''$$

$$\text{Length} = G\operatorname{cosec}\alpha = 1.676\operatorname{cosec}\alpha = 16.84\ m.$$

$$BH = \text{Distance}, DE = G\cot\alpha = 16.759\ m.$$

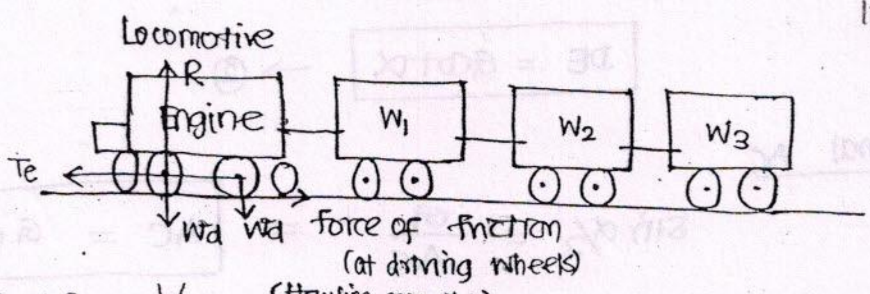
$$\text{Diagonal } AC = G\operatorname{cosec}\alpha/2 = \frac{1.676}{\sin\alpha/2} = 33.65\ m.$$

$$\text{Diagonal } BD = G\sec\alpha/2 = \frac{G}{\cos\alpha/2} = 1.678\ m.$$

#. TRACTION AND TRACTIVE EFFORT :

weight of train = wt of locomotive + wt. of all wagons.

$W_T = W_L + W_W$



$F = \mu R = \mu . W_d$

For the movement of a train three forces are important to understand.

1. Total resistance: Total resistance offered by the train and due to other reasons that restrict the movement of train.

2. Tractive effect of locomotive: The force applied by the engine on the driving wheels to overcome the resistances for movement of the train.

$T_e >$ Total resistance (for the train to move)

3. Hauling capacity:

This is the force of friction developed at driving wheels. This force of friction should be sufficient (not less than the tractive effort).

$$\text{Hauling capacity (H.C)} = \mu . R = \mu . W_d$$

W_d = total weight on the driving wheels.

If sufficient force of friction is not available, the train will not move even tractive effort is more than the total resistances.

#. sufficient weight must be there on driving wheels.

10.02.2014

#. Tractive effort of locomotive: