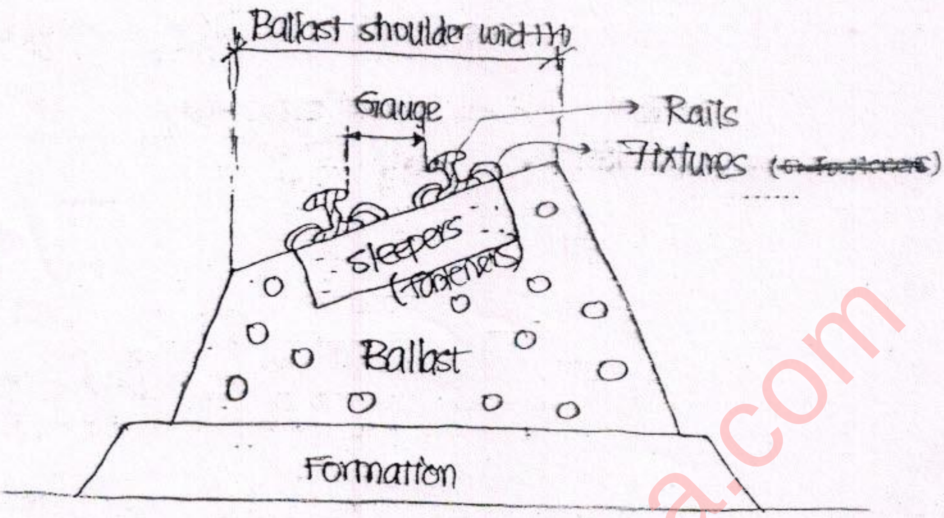
05.02.2014 Railway Engineering

Introduction :

1. Cross section of a railway track :



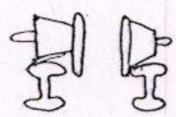
Existing ground (soil subgrade)

Important components :

(i) formation
(ii) Ballast
(iii) sleeper.
(iv) Fixtures
(v) Rails.

2. Gauge :

Distance between inner faces of the two rails (running face). Running face is the face on which flange of wheel will be there.

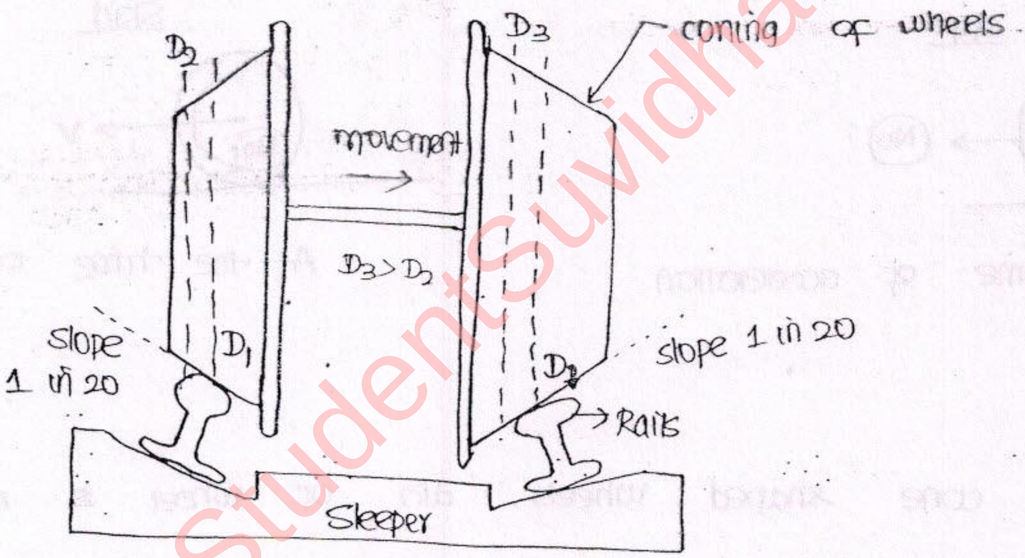


1. Broad Gauge (B.G) = 1.676 m
2. Meter Gauge (M.G) = 1.0 m
3. Narrow Gauge (N.G) = 0.762 m
4. light gauge (L.G) ([illegible] gauge) = 0.610 m

5. Standard gauge S.(G) = 1.435 m (other countries & metro).

Coning of wheels :

#. The wheels are made cone shaped having different diameter at different cross section. Diameter near flange is more than diameter near other ends. The rails are also laid at a slope of 1 in 20 (same slope of wheel face). This is called coning of wheels.

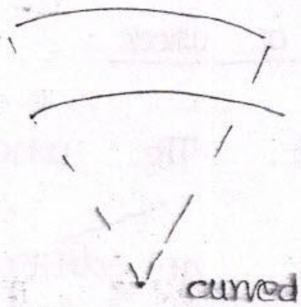


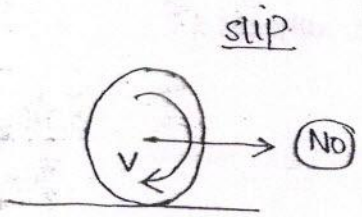
Purpose : ① On a straight track : to keep the wheel assembly in central position to avoid derailment.

② To reduce wear & tear of wheels as well as rails.

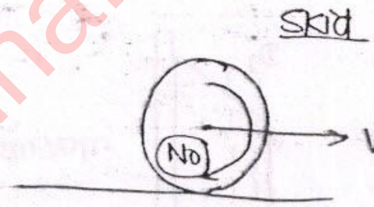
③ On a curved track : Due to centrifugal force, the wheel assembly will move in outward direction, so diameter on outer rail will increase, so the distance travelled in outer rail will become more as required.

Due to difference of dia on two rails, the train will be moving on a circular track will be adjusted as required. Only some part of difference is adjusted by coning. Remaining part is covered by slip or skid on the surface.





At the time of acceleration



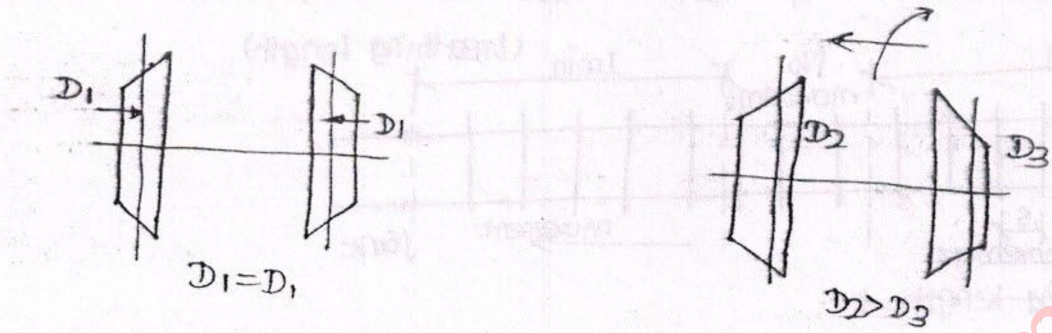
At the time of brake

Theory :

Due to cone shaped wheels, dia of wheel is not same at each cross section.

On a straight track :

The wheel will always move in central position in such a way that diameter at contact point with rail is same on the two rails. If the train (axle of wheel) try to move in any direction, diameter of wheel on ... the axle will start moving on a circular track, thus the wheel assembly will be automatically returned back in its central position.



central position

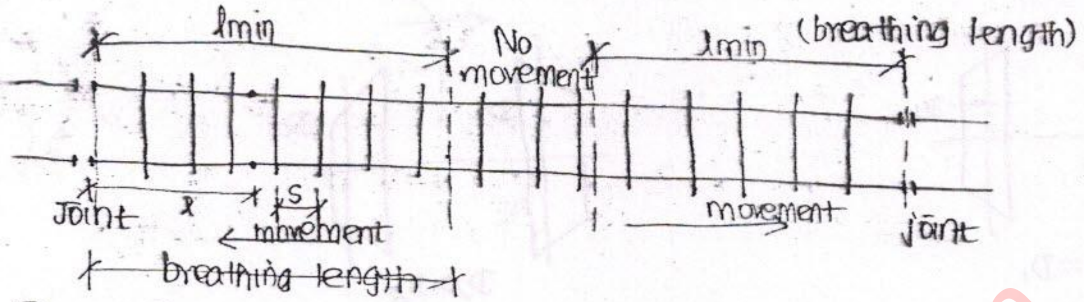
On a curved track: The distance on the two rails are partially adjusted due to centrifugal force due to which the train moves in outward direction, due to which dia on outer rail becomes more than dia. on inner rails.

3. Welded Rails (Long Welded Rails) LWR:

The rails are made of a particular length (for BG track, max. length 12.8 m is used). The joints to be provided in the railway tracks are one of the weakest locations. To avoid joints, rails are welded together.

⊕ Long welded rails are used where all the rails are welded for a long length. The stresses caused due to difference of temperature are arrested by the fixtures

-and rails are not allowed to move. So no expansion joints are required. A minimum length is required to avoid the movement of rail due to temperature variation.



If l = length of rail on one side. Increase in length due to $T°$ temp. variation

$$\delta l = l.\alpha.T$$

If no movement is allowed in the rail (strain not allowed)

$$= \frac{\delta l}{l} = \alpha T$$

$$\frac{\text{stress}}{\text{strain}} = E_s \text{ (Young's modulus of steel)}$$

stress develed in rails due to not allowing the movement of rail.

$$\text{stress} = \text{strain} \times E_s$$

$$p = \alpha.T.E_s.$$

Force developed in rails, $P = A \times p$

$$P = A.\alpha.T.E_s.$$

This force will be resisted by the fasteners (sleepers, If one sleeper can resist 'R' force, min. no of sleepers required to stop the movement of rail.

$$n = \frac{P}{R} = \frac{A.\alpha.T.E_s}{R}$$

Min. length in one direction so that there is no movement in rail due to temp. variation.

$$(l_{min})_{one\ direction} = (n-1)S.$$

Minimum length of long welded rail (so that there is no movement at central position) = $2 l_{min}$.

⊞ In central position There is no movement of rail because sufficient number of sleepers are available in both direction to stop the movement.

⊞ Breathing length : At both ends upto l_{min} distance from expansion joints, some movement of rail will be observed because no. of sleeper is less in one direction. These two end portions are called breathing length.

Q.5.a Define & explain breathing length of LWR
ES2001

II) Determine the min. theoretical length of LWR beyond which the central portion of a 52 kg rail would not be subjected to longitudinal movement due to 30°C temp variation. Use following data.

A. rails

c/s area = 66.15 cm²

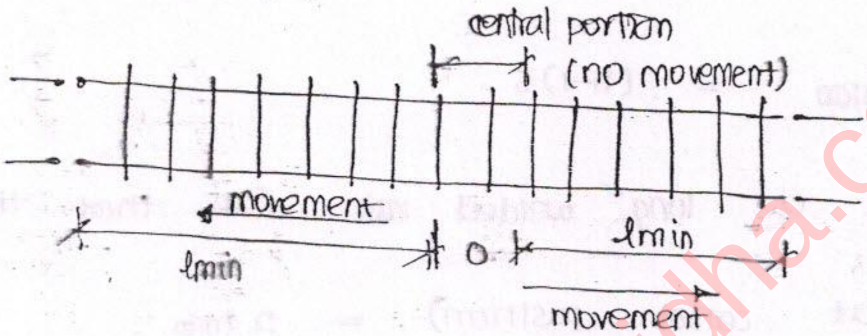
$E_s = 2.1 \times 10^6$ kg/cm²

$\alpha = 11.5 \times 10^{-6}$ /°C

B. sleepers

spacing = 60 cm

Average resistance force /sleeper/rail = 300 kg.



#. Due to temp. variation force developed in rail section

$$P = A . \alpha . T . E_s$$

$$= 66.15 \times 2.1 \times 10^6 \times 11.5 \times 10^{-6} \times 30$$

$$P = 47925.625 \text{ kg}$$

#. min. no. of sleepers req. to resist this force

$$n = \frac{47925.625}{300} = 159.75 \text{ i.e., } 160.$$

#. min length in one direction

$$l_{min} = (n-1) s = (160-1) \times 60 = 9540 \text{ cm}$$

$$= 95.4 \text{ m.}$$

(breathing length)

#. min. length of LWR = $2 l_{min}$ = 2 × 95.4 = 190.8 m

4. Sleeper density :

#. Number of sleepers used for one rail is called sleeper density.

#. denoted by (n+x)

n → length of one rail in meter (For BG track = 12.8 m ≃ 13 m)

#. Generally sleeper density is kept from (n+3) to (n+6).

Eg. calculate total no. of sleepers req. for 5 km railway track if sleeper density is n+5 for a BG track.

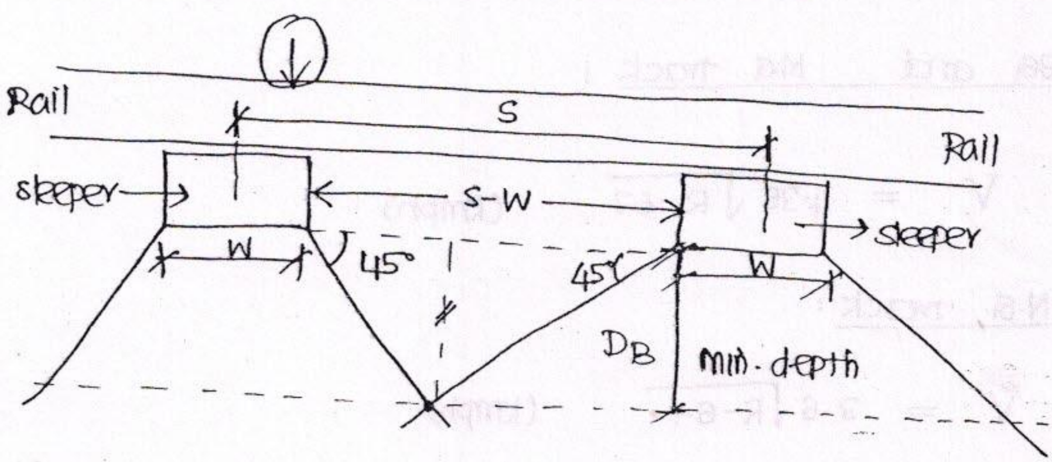
one rail length = 12.8 m ≃ 13 m

No. of sleepers used = (n+5) = (13+5) = 18

Total no. of sleepers for 5 km = $\frac{5000}{12.8} \times 18 = 7031.25$

say 7032 sleepers

#. Minimum depth of Ballast cushion :



If S = spacing of sleepers

W = width of one sleeper

min. depth of ballast cushion required, $D_B = \frac{S-W}{2}$

Geometrical design :

① Design speed :

Design speed shall be minimum of the following :-

(i) max. speed allowed by railway (max. sanctioned speed)

(ii) max. speed allowed on a curved track (as per radius)

(speed as per Martin's formula).

(iii) As per super elevation provided (super elevation or cant).

(iv) As per length of transition curve.

#. Martin's formula :

(i) For transition curve : (where transition curve have been provided with simple curve).

a) for BG and M.G track :

$$V = 4.35\sqrt{R-67} \quad (\text{Kmph})$$

b) For N.G track :

$$V = 3.6\sqrt{R-6.1} \quad (\text{Kmph})$$

$R \rightarrow$ radius of curve in metres

2. <u>For non-transitioned curve</u>: (only simple curve is provided)

V = 80% of design speed for transitioned curve.

a) <u>For BG and M.G track</u>:

$$V = 0.8 \times 4.35 \times \sqrt{R-67}$$

b) <u>For N.G track</u>:

$$V = 0.8 \times 3.6 \times \sqrt{R-6.1}$$

3. <u>For high speed train</u>:

$$V_{max} = 4.58\sqrt{R} \quad (\text{kmph})$$

R → radius in meter.

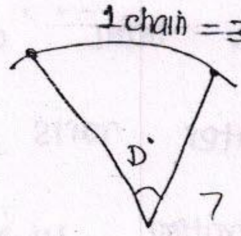
Martin's formula is used for calculating max. speed allowed on a curve location. (bcz, all formulae depends on R). R → radius of curve in meter.

06.02.2014

<u>Radius of curve / Degree of curve</u>:

→ Degree of curve is the angle formed at centre by 1 chain length of the curve.

1. <u>For 30m chain</u>: $D^\circ = \frac{1718.9}{R}$



$$\frac{2\pi R}{360} = \frac{30m}{D^\circ} \Rightarrow \boxed{D^\circ = \frac{1720}{R}}$$

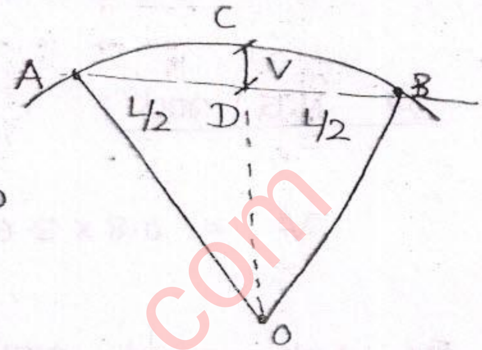
7

2. For 20m chain :

$$\boxed{D^\circ = \frac{1146}{R}}$$

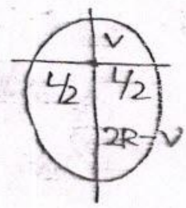
	1°	2°	3°	4°	5°
30m	1720	860	573	430	344
20m	1146	573	382	287	230

Versine of curve :



For a chord AB of length L as shown in fig, distance CD is called versine of curve.

Using property of circle,

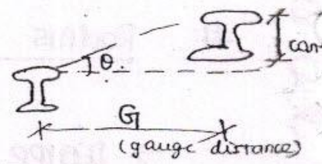


$$\frac{L}{2} \times \frac{L}{2} = V\,(2R - V) \qquad 2R - V \simeq 2R$$

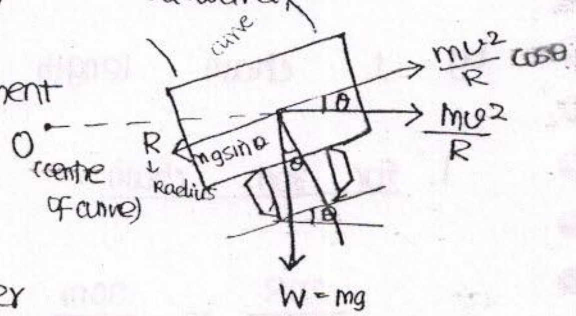
$$= 2R.V$$

$$\boxed{V = \frac{L^2}{8R}} \text{ (versine of curve)}$$

Cant (Super elevation) :



When the train is moving on a horizontal curve, centrifugal force will be acting in outward radial direction. To avoid the derailment of train due to centrifugal force outer rails are provided at higher elevation w.r to inner rails to counteract the effect of centrifugal force.



curve horizontal → centrifugal force horizontal.

curve inclined → centrifugal force inclined

W = weight of train

In this case, there is no force of friction between rail and wheel in lateral direction.

outward force along surface of rail = component of weight in inward direction.

$$\frac{mv^2}{R}\cos\theta = mg\sin\theta \Rightarrow \boxed{\tan\theta = \frac{v^2}{gR}} \rightarrow (1)$$

$$\tan\theta = \frac{cant}{G} \Rightarrow cant = G.\tan\theta = \frac{G.v^2}{gR} \rightarrow (2)$$

If V → speed in kmph

$$v = \frac{1000\,V}{3600} = 0.278\,V$$

$$cant = \frac{G \times (0.278\,V)^2}{g \cdot R} = \frac{GV^2}{127\,R}$$

(g = 9.81)

$$\boxed{cant = \frac{GV^2}{127R}} \rightarrow (A) \quad \text{cant formula}$$

G = 1.676 m for B.G

= 1.0 m for M.G.

Equilibrium speed :

Different trains move with different speeds on a track. so an average cant is provided so that all type of trains can safely run on the track avoiding the chance of derailment.

1. If max. speed (V_{max}) > 50 kmph

Equilibrium speed $= \frac{3}{4} V_{max}$ (or) safe speed as per Martin's formula (minimum of two).

2. If max. speed (V_{max}) < 50 kmph

Equilibrium speed $= V_{max}$ (or) safe speed by Martin's formula.

3. <u>Equilibrium speed based on weighted average</u> :

$$V_{eq} = \frac{n_1 V_1 + n_2 V_2 + n_3 V_3 + \cdots}{n_1 + n_2 + n_3 + \cdots}$$

where n_1, n_2, n_3 are no. of trains running at $V_1, V_2, V_3, \ldots$ speed.

#. <u>Max. limit of Actual super elevation (cant) provided on the track</u> :

	When speed < 120 kmph	When speed > 120 kmph
B.G	16.50 cm	18.50 cm
M.G	10.0 cm	—x—
N.G	7.6 cm	—x—

cant deficiency :

Eg:

For a B.G track, max. speed of train = 110 kmph

3° curve.

If nothing given, take 30m chain length

$$R = \frac{1720}{3^\circ} = 573\,m$$

Max. cant reqd. for max. speed, $e = \frac{GV^2}{127R}$

$$= \frac{1.676 \times 110^2}{127 \times 573} = 0.2786\,m$$

$$= 27.86\,cm.$$

Max. actual (theoretical) cant that can be provided = 16.50 cm

cant deficiency = $e_{max} - e_{actual}$ (or) $e_{max} - e_{theoretical}$

$$= 27.86 - 16.50 = 11.36\,cm.$$

The actual cant is provided for an average speed or as per max. allowed cant value.

The deficiency of cant required for high speed train as per the value of actual cant provided is called cant deficiency.

The trains can move with some limited value of cant deficiency.

Limits of cant deficiency :-

	When speed < 100 kmph	When speed > 100 kmph
B.G	7.6 cm	10.0 cm
M.G	5.10 cm	—x—
N.G	3.80 cm	—x—

Eg. same example :

1. Actual cant provided :

$e_{actual} = 16.50 \text{ cm} = 0.165 \text{ m}$

The above value is related with average (Eq.) speed.

$$e_{act} = \frac{G.V_{eq}^2}{127R} \Rightarrow V_{eq} = \sqrt{\frac{127.R.e_{act}}{G}}$$

$$= \sqrt{\frac{127 \times 573 \times 16.50 \times 10^{-2}}{1.676}} = 84.64 \text{ kmph}$$

(metre)

2. Theoretical cant :

e_{th} = Actual cant + max. cant deficiency

$$\boxed{e_{th} = e_{act} + D_{max}} \longrightarrow ①$$

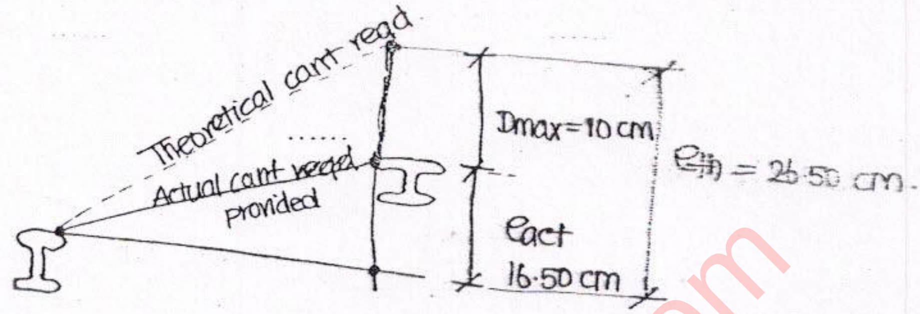
$e_{th} = 16.5 + 10 = 26.50 \text{ cm} = 0.265 \text{ m}.$

max cant deficiency = 10 cm

Max speed that can be allowed :

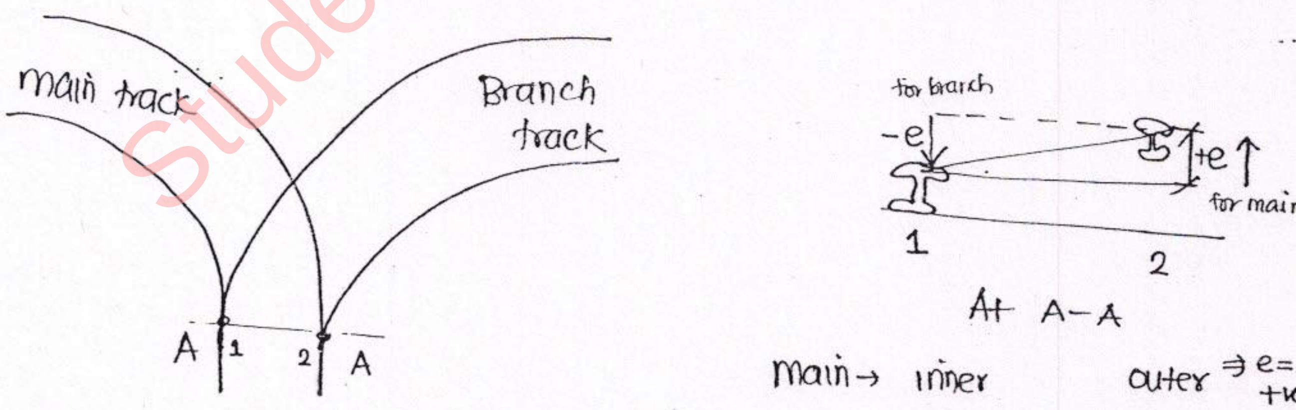
$$V_{max} = \sqrt{\frac{127 \times R \times e_{th}}{G}} = \sqrt{\frac{127 \times 573 \times 0.2650}{1.676}} \rightarrow \text{metre}$$

$$= 107.26 \text{ Kmph.}$$



Negative superelevation :

If outer rail has been provided at lower elevation as compared to inner rail, it is called negative super elevation.

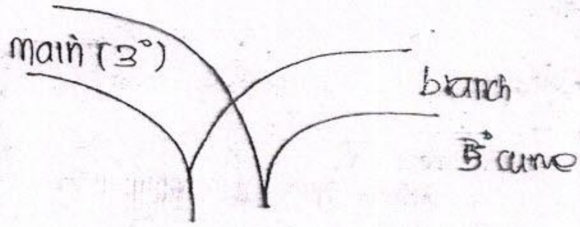


main → inner outer ⇒ e = +ve

branch → outer inner

Q.1. A branch track of 5° curve is diverted in opp. dxn from a 3° curve (main). If max. speed allowed on main track is 70 kmph, calculate max. speed allowed on branch track consider both track as BG track. max cant deficiency = 7.6 cm

Radius of curve :



$R_{main} = \frac{1720}{3°} = 573\ m$

$R_{branch} = \frac{1720}{5°} = 344\ m.$

Actual cant is calculated from average speed.

Theoretical cant is calculated from max. speed.

1. **For main track :**

max. speed = 70 Kmph

Theoretical cant :

$$e_{th} = \frac{G.V^2}{127\ R_{main}} = \frac{1.676 \times 70^2}{127 \times 573}$$

$$= 11.29\ cm.$$

$e_{th} = e_{act} + D_{max}.$

Actual cant provided on main track

$e_{act} = 11.29 - 7.60\ cm \simeq +3.69\ cm.$

2. **For branch track :**

Actual cant available = -3.69 cm.

Theoretical cant for branch track $= e_{act} + D_{max}$

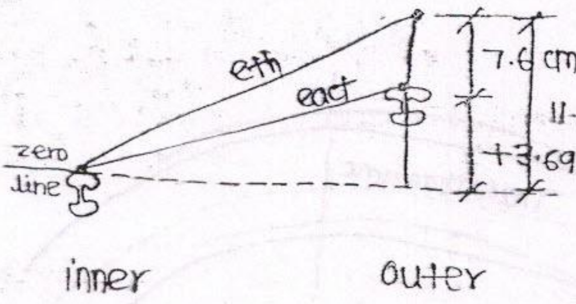
$= -3.69 + 7.6 = 3.91$ cm

$$V_{max} = \sqrt{\frac{127 \times R_{branch} \times e_{th}}{G}} = \sqrt{\frac{127 \times 344 \times 0.0391}{1.676}} \text{ (metre)}$$

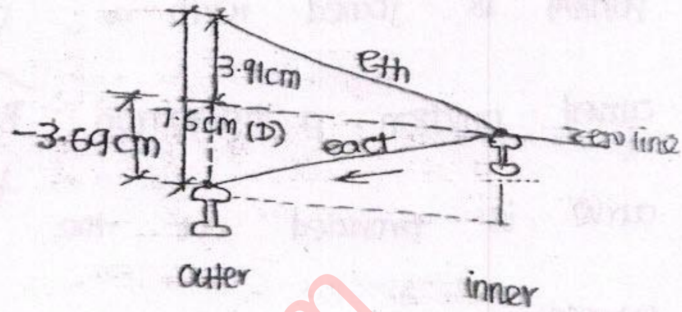
= 31.925 kmph.

For main track

line joined from inner to outer.



For branch track



b) If max. speed allowed on branch track is 40 kmph, calculate what max. speed can be allowed on main track.

1. For branch track :

$R_{branch} = 344$ m

$R_{main} = 573$ m.

$V_{max} = 40$ kmph.

$$e_{th} = \frac{G.V_{max}^2}{127 \times R_b} = \frac{1.676 \times 40^2}{127 \times 344} = 0.06138 \text{ m}$$
$$= 6.138 \text{cm}$$

$e_{th} = e_{act} + D_{max} \Rightarrow e_{act} = 6.138 - 7.6 = -1.462$ cm

2. For main track :

$e_{act} = e_{th} - D_{max}$

$e_{act} = +1.462$ cm $\Rightarrow e_{th} = e_{act} + D_{max}$

$= 1.462 + 7.6 = 9.062$ cm

$= 0.09062$ m.

$$V_{max} = \sqrt{\frac{127 \times R_m \times e_{th}}{G}}$$

$$= \sqrt{\frac{127 \times 573 \times 0.09062}{1.676}} = 62.72 \text{ Kmph.}$$