CIVIL ENGINEERING

TRANSPORTATION ENGINEERING

Volume-1: Study Material with Classroom Practice Questions
Chapter- 1
Highway Development and Planning

01. Ans: (d)

Sol:

<table>
<thead>
<tr>
<th>Road</th>
<th>Length (km)</th>
<th>Number of with population</th>
<th>Utility</th>
<th>Utility/km</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>&lt; 2000</td>
<td>2000 – 5000</td>
<td>&gt; 5000</td>
</tr>
<tr>
<td>P 20</td>
<td>8</td>
<td>6</td>
<td>1</td>
<td>8×0.5+6×1+1×2 = 12</td>
</tr>
<tr>
<td>Q 28</td>
<td>19</td>
<td>8</td>
<td>4</td>
<td>19×0.5+8×1+4×2 = 25.5</td>
</tr>
<tr>
<td>R 12</td>
<td>7</td>
<td>5</td>
<td>2</td>
<td>7×0.5+5×1+2×2 = 12.5</td>
</tr>
<tr>
<td>Weightage factor</td>
<td>0.5</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

∴ RQP

02. Ans: (a)

Sol:

<table>
<thead>
<tr>
<th>Road Lane</th>
<th>Length (cm)</th>
<th>Number of villages with population ranges</th>
<th>Industrial Product</th>
<th>Utility</th>
<th>Utility/km</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1000-2000</td>
<td>2000-5000</td>
<td>5000-10000</td>
<td>&gt;10000</td>
</tr>
<tr>
<td>P 300</td>
<td>100</td>
<td>80</td>
<td>30</td>
<td>6</td>
<td>200</td>
</tr>
<tr>
<td>Q 400</td>
<td>200</td>
<td>90</td>
<td>00</td>
<td>8</td>
<td>270</td>
</tr>
<tr>
<td>R 500</td>
<td>240</td>
<td>110</td>
<td>70</td>
<td>10</td>
<td>315</td>
</tr>
<tr>
<td>S 550</td>
<td>248</td>
<td>112</td>
<td>73</td>
<td>12</td>
<td>335</td>
</tr>
<tr>
<td>Weightage factor</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

∴ RSPQ
Chapter - 4
Highway Geometric Design - Gradients

Common data for Questions 01 & 02

01. Ans: (b)
Sol: Height of crown = \( \frac{W}{2n} = \frac{3.5 \times 1000}{2 \times 60} \)
= 29.2 mm

02. Ans: (d)
Sol: Height of crown = \( \frac{W}{2n} = \frac{3.5 \times 1000}{2 \times 40} \)
= 43.75 mm

04. Ans: (a)
Sol: G.C = \( \frac{30 + R}{R} \)
G.C = \( \frac{30 + 50}{50} = 1.6 \)
Max G.C = \( \frac{75}{50} = 1.5 \) ∴ G.C = 1.5

The compensated gradient = 6% – 1.5
= 4.5%

05. Ans: (a)
Sol: Height of crown = \( \frac{W}{2n} \)
\( \frac{W}{2n} = 7.5 \)
2n = \( \frac{9 \times 100}{7.5} \)
n = 60 ⇒ 1 in 60

Chapter - 5
Highway Geometric Design - Sight Distances

01. Ans: (c)
Sol: B.D = 16 m,
f = 0.4
\( \frac{V^2}{254f} = 16 \) ⇒ \( \frac{V^2}{254 \times 0.4} = 16 \)

V = 40.3 kmph ≈ 40 kmph

02. Ans: (e)
Sol: V = 30 kmph,
f = 0.4
BD_{down} = 2 \ BD_{up}
\( \frac{V^2}{254(f + 0.01n)} = 2 \times \frac{V^2}{254(f - 0.02n)} \)
f + 0.01 n = 2 f – 0.02 n
0.03 n = 0.4
n = 13.33%

03. Ans: (b)
Sol: V = 72 kmph, n = 2%,
f = 0.15,
t = 1.5 sec

SSD = 0.278 Vt + \( \frac{V^2}{254(f + 0.01n)} = 150 \) m
04. Ans: (b)
Sol: $V = 60$ kmph
\[ t = 2.5 \text{ sec , } f = 0.36 \]
\[ 0.278Vt + \frac{V^2}{254(f + 0.01n)} = 6 \]
\[ 0.278 \times 60 \times 2.5 + \frac{60^2}{254(0.36 + 0.01n)} \]
\[ n = 4.78 \approx 4.8 \]

05. Ans: (c)
Sol: $V = 60$ kmph, $t = 2.5$ sec, $f = 0.35$
\[ \text{SSD} = 0.278Vt + \frac{V^2}{254f} \]
\[ = 0.278 \times 60 \times 2.5 + \frac{60^2}{254 \times 0.35} = 82.1 \text{ m} \]
\[ \text{SSD for single two way traffic} = 2 \times \text{SSD} \]
\[ = 2 \times 82.1 = 164.2 \text{ m} \]

06. Ans: (c)
Sol: ISD = $2 \times 80 = 160$ m

07. Ans: (83 kmph)
Sol: There are 3 phases in the problem
1. Driver lifts foot from accelerator and moves it to brake pedal – the velocity is uniform.
2. Deceleration increases from zero to maximum
3. Braking system locks the wheels and deceleration assumed to be constant until vehicle strikes the stationary vehicle
\[ A = fg = 0.75 \times 9.81 = 7.35 \text{ m/s}^2 \]
\[ \text{During 1st phase, assume driver reaction time} 0.5 \text{ sec} \]
\[ v_o = v_f + \frac{a}{2} (t_1 - t_o) \]
\[ \text{During 3rd phase, deceleration assumed to be uniform} \]
\[ v_1 = \sqrt{v_2^2 + 2aS} = \sqrt{11.18^2 + 2 \times 7.35 \times 27.45} \]
\[ = 22.98 \text{ m/s} = 82.76 \text{ kmph} \]
\[ v_o = 82.76 + \frac{7.35}{2}(0.8 - 0.5) \]
\[ = 83 \text{ kmph} \]

08. Ans: (13.6 m)
Sol: \[ \frac{dv}{dt} = 3 - 0.04v \]
\[ A = 3, \beta = 0.04, t = 5 - 0.75 = 4.25 \]
\[ \text{Width of intersection} = 7.5 \text{ m} \]
\[ \text{Equation for distance as a function of time} \]
\[ x = \frac{\alpha t}{\beta} - \frac{\alpha}{\beta^2} (1 - e^{-\beta t}) + \frac{v_o}{\beta} (1 - e^{-\beta t}) \]
\[ v_o = \text{initial speed} = 0 \]
\[ x = \frac{3(4.25)}{0.04} \left( 1 - e^{-0.04 \times 4.25} \right) + 0 \]

\[ x = 25.62 \text{ m} \]

Intersection + length of car

\[ 7.5 + 6.1 = 13.6 \text{ m} \]

\[ \therefore \text{He can clear the intersection} \]

\[ \text{Ans: } T = 7.13 \text{ sec, } V = 138 \text{ kmph} \]

\[ \text{Sol:} \]

\[ \frac{20}{20} \rightarrow 230 \text{ m} \]

\[ \frac{20}{40} \rightarrow x \]

\[ x = 115 \text{ m} \]

In question they give it will take 3 sec to red sign

So

Speed of \( \frac{20}{40} \) vision driver = \( \frac{115}{3} \) m/sec

= 138 kmph

For speed of \( \frac{20}{40} \) vision driver is 58kmph

i.e \( \frac{58 \times 5}{18} = 16.11 \text{ m/sec} \)

Velocity = \( \frac{D}{T} \)

\[ T = \frac{115}{16.11} \]

\[ T = 7.13 \text{ sec} \]

10. Ans: 142

\[ \text{Sol: For normal driver with 6/6 vision the position of sign post is shown below.} \]

\[ S_1 = 48 \text{ m} \]

\[ S_2 = ? \]

\[ S = 174 \text{ m} \]

\[ S_2 = 174 - 48 = 126 \text{ m} \]

\[ S_2 = \text{The distance from sign post to the start of zone-y} \]

\[ S_1 = \text{Distance traveled by the vehicle during perception – reaction time for 6/6 vision driver} \]

\[ S = \text{total distance required to reduce the speed to 30 kmph from design speed.} \]

For a driver with 6/9 vision (with defective sight), the distance of sign post should be nearer as compared to driver with normal sight.

\[ \therefore \text{Modified } S_1 = \frac{6}{9} \times 48 = 32 \text{ m} \]

\[ \text{The position of sign post is as shown below} \]

\[ \frac{A}{S_1 = 32 \text{ m}} \]

\[ S = 174 \text{ m} \]

\[ \frac{S_2 = X = ?}{C} \]

\[ \text{The distance from modified position of sign post to the start of zone-y (i.e. C’B)} \]

\[ = 174 - 32 = 142 \text{ m.} \]

11. Refer previous GATE solutions Book

(Cha-2, Two marks 9th Question -pg: 821)
Chapter- 6
Highway Geometric Design
- Overtaking Sight Distance

Common data for Questions 01, 02 & 03

01. Ans: (c)
Sol: \( V = 80 \text{ kmph} \ a = 2.5 \text{ kmph/sec} \)
\( V_b = 50 \text{ kmph} \ S = 16 \text{ m} \)
\( t = 2 \text{ sec} \)
\[
T = \sqrt{\frac{14.4s}{a}} = \sqrt{92.16 \text{ sec}}
\]
\( = 9.6 \text{ sec} \)
OSD = \( d_1 + d_2 \)
\( = 0.278 V_b t + (0.278 V_b T + 2s) \)
\( = 193.24 \text{ m} \)

02. Ans: (d)
Sol: OSD = \( d_1 + d_2 + d_3 \)
\[
= 0.278 V_b t + (0.278 V_b T + 2s) + 0.278 VT
\]
\( = 406.74 \text{ m} \)

03. Ans: (c)
Sol: Since division is there
OSD = \( d_1 + d_2 \)
\( = 193.24 \text{ m} \)

Common data for Questions 04 & 05

04. Ans: (c)
Sol: \( V = u + at \)
\( u = 100 \text{ kmph} \)
\( = 27.7 \text{ m/s} \)

05. Ans: (d)
Sol: Distance traveled in overtaking process (d_2)
\[
d_2 = (V_b T + 2 s)
\]
\( = (V_b T + S_1 + S_2) \)
\( S_1 = 25 \text{ m} \)
\( S_2 = 20 \text{ m} \)
\[
T = \sqrt{\frac{4s}{a}} = 10.6 \text{ sec}
\]
\( d_2 = (0.278 \times 100 \times 10) + (25 + 20) \)
\( = 323 \text{ mm} \)

Common data for Questions 06 & 07

06. Ans: (c)
Sol: OSD = \( d_1 + d_2 \)
\( V = 22.22 \text{ m/s} \)
\( V_b = 16.67 \text{ m/s} \)
\( a = 0.7 \text{ m/s}^2 \)
\( S = (0.7 V_b + l) = 17.67 \text{ m} \)
\[
T = \frac{4s}{a} = 10.05 \text{ sec}
\]
\( t = 2 \text{ sec} \)
OSD = \( d_1 + d_2 + d_3 \)
\[ V = V_b \times T + (V_b \times T + 2s) + VT \]
\[ = 236.21 + (22.22 \times 10.05) \]
\[ = 459.521 \text{ m} \]
\[ \approx 460 \text{ m} \]

07. Ans: (d)
Sol: Desirable length of OZ = 5 OSD
\[ = 5 (d_1 + d_2 + d_3) \]
\[ = 5 \times 460 \]
\[ \approx 2300 \text{ m} \]

Chapter- 7
Highway Geometric Design
- Horizontal Curves

Common data for Questions 01 & 02
01. Ans: (a)
Sol: \[ e = V^2 \]
\[ = \frac{225}{225 \times 600} = 0.031 \]
\[ E = e \times w = 0.031 \times 7 = 0.22 \text{ m} \]
w.r.t centre line = 0.11 m

02. Ans: (b)
Sol: w.r.t inner edge ; \[ E = 0.22 \text{ m} \]

03. Ans: (c)
Sol: \[ e_{cal} = \frac{V^2}{225R} = \frac{65^2}{225 \times 125} = 0.15 \]
\[ e_{cal} > 0.07 \]
\[ \therefore V = 65 \text{ kmph is not suitable} \]
\[ 0.07 + f = \frac{V^2}{127R} \rightarrow f = \frac{65^2}{127 \times 125} - 0.07 \]
\[ = 0.196 > 0.15 \]
\[ V_a \text{ should be calculated} \]

04. Ans: (b)
Sol: \[ e + f = \frac{V^2}{127R} \]
\[ e + 0.15 = \frac{100^2}{127 \times 500} \]
\[ \Rightarrow e = 0.00748 = 0.74\% \]

05. Ans: (b)
Sol: \[ f = \frac{V^2}{127R} = \frac{100^2}{127 \times 500} = 0.157 \approx 0.16 \]

06. Ans: (c)
Sol: \[ f = 0 ; \quad e + 0 = \frac{100^2}{127 \times 500} \]
\[ \Rightarrow e = 15.75\% \]
7. Ans: (a)
Sol: \( e = \frac{V^2}{225R} = \frac{60^2}{225 \times 500} = 0.032 = 3.2\% \)

8. Ans: (b)
Sol: \( R_{Ruling} = \frac{V^2}{127(f + e)} \)
\[ = \frac{100^2}{127(0.07 + 0.13)} \]
\[ = 393.7 \text{ m} \approx 395 \text{ m} \]

9. Ans: (a)
Sol: \( b = 2.4 \text{ m} \)
\( h = 4.2 \text{ m} \)
\[ \frac{b}{2h} = \frac{2.4}{2 \times 4.2} = 0.286 > f \]
\[ \frac{b}{2h} > f \]
\[ \therefore \text{Lateral skidding occur first} \]

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Chapter- 8
Horizontal Curves (Extra Widening)

Common data for Questions 01 & 02

1. Ans: (d)
Sol: \( e + f = \frac{V^2}{127R} \)
\[ R_{Ruling} = \frac{76^2}{127\left(\frac{1}{15} + 0.15\right)} = 209.9 \text{ m} \]

2. Ans: (d)
Sol: \( W_e = \frac{n \ell^2}{2R} + \frac{V}{9.5\sqrt{R}} \)
\[ = \frac{2 \times 7^2}{2 \times 209} + \frac{76}{9.5 \sqrt{209}} = 0.787 \text{ m} \]
\[ \therefore \text{Total width} = 7 + 0.787 \]
\[ = 7.78 \text{ m} \]

3. Ans: (c)
Sol: \( W_e = \frac{n \ell^2}{2R} + \frac{V}{9.5\sqrt{R}} \)
\[ = \frac{2 \times 8^2}{2 \times 300} + \frac{100}{9.5 \sqrt{300}} = 0.821 \text{ m} \]

4. Ans: (c)
Sol: Given \( W_m = 0.096 \)
\[ \frac{\ell^2}{2R} = 0.096 \Rightarrow R = 226.87 \text{ m} \]
\[ W_e = W_m + W_{ps} = \frac{n \ell^2}{2R} + \frac{V}{9.5\sqrt{R}} \]
\[ = \frac{2 \times 6.6^2}{2 \times 226.87} + \frac{80}{9.5 \sqrt{226.87}} = 0.75 \text{ m} \]
Chapter 9
Set Back Distance and Curve Resistance

01. Ans: (a)
Sol: Set back or the clearance is the distance required from the centre line of horizontal curve to an obstruction on the inner side of the curve to provide adequate sight distance at a horizontal curve.

02. Ans: (c)
Sol: 
\[ m = \frac{S^2}{8R} \Rightarrow R = \frac{80^2}{8 \times 10} = 80 \text{ m} \]

Common data for Questions 03 & 04

03. Ans: (c)
Sol: 
\[ L = 180 \text{ m} \quad S = 80 \text{ m} \]
\[ L > S \]
\[ m = \frac{S^2}{8R} = \frac{80^2}{8 \times 360} = 2.22 \text{ m} \]
Width of pavement is not indicated
\[ m = R - R \cos \left( \frac{\alpha}{2} \right) \]
\[ \frac{\alpha}{2} = \frac{180S}{2 \pi R} = \frac{180 \times 80}{2 \pi \times 360} = 6.36 \]
\[ m = 360 - 360 \cos (6.36) \]
\[ = 2.2 \text{ m} \]

04. Ans: (c)
Sol: 
\[ L = 180 \text{ m} \quad S = 250 \text{ m} \]
\[ L < S \]
\[ m = R - R \cos \left( \frac{\alpha}{2} \right) + \frac{S - L}{2} \sin \left( \frac{\alpha}{2} \right) \]
\[ \frac{\alpha}{2} = \frac{180L}{2 \pi R} = \frac{180 \times 180}{2 \pi \times 360} = 14.32 \]
\[ m = 360 - 360 \cos (14.32) + \frac{250 - 180}{2} \sin (14.32) = 19.85 \text{ m} \]

Common data for Questions 05 & 06

05. Ans: (c)
Sol: 
\[ SSD = 0.278 V t + \frac{V^2}{254 f} \]
\[ = (0.278 \times 80 \times 2.4) + \frac{80^2}{254 \times 0.355} \]
\[ = 124.35 \text{ m} \approx 125 \text{ m} \]

06. Ans: (d)
Sol: 
\[ S = 125 \text{ m} \]
\[ d = \frac{W}{4} = \frac{7}{4} = 1.75 \text{ m} \]
\[ \frac{\alpha}{2} = \frac{180S}{2 \pi (R - d)} = \frac{180 \times 125}{2 \pi (200 - 1.75)} = 18.06 \]
\[ m = R - (R - d) \cos \left( \frac{\alpha}{2} \right) \]
\[ = 11.52 \text{ m} \]
\[ m^1 = m - d \]
\[ = 11.52 - 1.75 = 9.77 \text{ m} \]
Problems on Curve Resistance

01. Sol: Let ‘T’ is the original Tractive force
    loss of tractive force = T(1– cosθ)
    = T(1–cos45°)
    Ratio of loss of Tractive force to original is
    = 0.243

02. Sol: Curve resistance = T(1 – cosθ)
    = T(1–cos30°)
    = 0.134 T

03. Sol: Curve resistance = T(1–cosθ)
    = T(1–cos90°)
    = 0
04. Ans: (a)
Sol: Considering ‘C’ value
\[ L = \frac{0.0215 V^3}{CR} = \frac{0.0215 \times 80^3}{0.516 \times 900} = 23.7 \text{ m} \]
Considering ‘N’ value
\[ e = \frac{V^2}{225R} = \frac{80^2}{225 \times 900} = 0.0316 \]
(for mixed traffic)
\[ L = \frac{e N}{2} (W + W_e) \]
\[ = \frac{0.0316 \times 150}{2} \times 7 = 16.59 \text{ m} \]
Considering terrain
\[ L = \frac{2.7 V^2}{R} = \frac{2.7 \times 80^2}{900} = 19.2 \text{ m} \]
\[ \therefore \text{Length of T.C} = 23.7 \text{ m} \]

02. Ans: (d)
Sol: \( N = 4 - (-2) = 6\% \)
\[ 6\% \rightarrow 150 \text{ nm} \]
\[ 4\% \rightarrow \frac{4}{6} \times 150 = 100 \text{ m} \]

03. Ans: (c)
Sol: \( N = \frac{\frac{1}{50} - \left( -\frac{1}{100} \right)}{\frac{1}{50} - \frac{1}{100}} = 0.03 = 3\% \)
\[ 1\% \rightarrow 100 \text{ m} \]
\[ 3\% \rightarrow \frac{3}{1} \times 100 = 300 \text{ m} \]

Common data for Q 04 & 05

04. Ans: (c)
Sol: \( N = \frac{\frac{1}{25} - \left( -\frac{1}{50} \right)}{\frac{1}{25} - \frac{1}{50}} = 0.06 = 6\% \)
\[ S = 180 \text{ m} \]
Take \( L > SSD \)
\[ L = \frac{NS^2}{4.40} = \frac{0.06 \times 180^2}{4.4} = 441.8 \text{ m} \]
\[ \approx 442 \text{ m} \]

05. Ans: (b)
Sol: \( 6\% \rightarrow 442 \text{ m} \)
\[ 4\% \rightarrow \frac{4}{6} \times 442 = 294.66 \text{ m} \]
\[ = 294.66 \]
06. Ans: (b)
Sol: \[ N = \frac{1}{100} - \left(\frac{-1}{120}\right) = 0.0183 \]
Assume \( L > OSD \)
\[ L = \frac{NS^2}{9.6} = \frac{0.0183 \times 470^2}{9.6} = 421.09 \text{ m} \]
421.09 < 470
Take \( L < OSD \)
\[ L = 2S - \frac{9.6}{N} = 2 \times 470 - \frac{9.6}{0.0183} = 406.66 \text{ m} \]

07. Ans: (a)
Sol: Refer previous GATE solutions Book
(Cha-2.8, Two marks 5th Question - pg: 830)

08. Ans: (c)
Sol: Take \( L \geq OSD \)
\[ L = \frac{NS^2}{9.6} = \frac{0.018 \times 500^2}{9.6} = 468.75 \text{ m} < 500 \text{ m} \]
Take \( L < OSD \)
\[ L = 2S - \frac{9.6}{N} = 2 \times 500 - \frac{9.6}{0.018} = 466.67 \text{ m} < 500 \text{ m} \]
\( \therefore \) Length of summit curve,
\[ L \approx 467 \text{ m} \]
03. Ans: (a)
Sol: For 9% → 373.86
For 4% → ?
\[ \frac{4 \times 374.0}{9} = 166.22 \text{ m} \]
\[ \approx 166 \]

01. Ans: (a)
Sol: \[ k_1d_1 = k_2d_2 \]
\[ (200) \times (30) = (k_2) (75) \]
\[ k_2 = k_{soil} = 80 \text{ N/cm}^3 \]

03. Ans: (a)
Sol: \[ E = \frac{1.18 \times 800 \times (75/2)}{2.5 \times 10^{-1}} \]
\[ = 141600 \text{ N/cm}^2 \]
\[ = 141.6 \text{ kN/cm}^2 \]

04.
Sol: Total weight = 825 + 1200 + 325 + 150 + 100 = 2600 gm
% wt of material;
\[ A_1 \rightarrow \frac{825}{2600} \times 100 = 31.7\% \]
\[ A_2 \rightarrow \frac{1200}{2600} \times 100 = 46.15\% \]

\[ A_3 \rightarrow \frac{325}{2600} \times 100 = 12.5\% \]
\[ A_4 \rightarrow \frac{150}{2600} \times 100 = 5.7\% \]

Bitumen → \[ \frac{100}{2600} \times 100 = 3.8\% \]

\[ G_1 = \frac{100}{ \left( \frac{w_1}{G_1} + \frac{w_2}{G_2} + \frac{w_3}{G_3} + \frac{w_4}{G_4} + \frac{w_5}{G_5} \right) } \]
\[ = \frac{31.7 + 46.15 + 12.5 + 5.7 + 3.8}{2.63 + 2.51 + 2.46 + 2.43 + 1.05} \]
\[ = 2.41 \]

\[ G_m = \frac{1100}{475} = 2.31 \]
(a) \[ V_a = \frac{G_1 - G_m}{G_1} \times 100 = \frac{2.41 - 2.31}{2.41} \times 100 = 4.15\% \]
(b) \[ V_b = \frac{w_b}{G_b} \times G_m = \frac{3.80}{1.05} \times 2.31 = 8.36 \]
(c) \[ VMA = V_a + V_b = 4.15\% + 8.36 = 12.51\% \]

\[ VFB = \frac{V_b}{VMA} \times 100 \]
\[ = \frac{8.36}{12.51} \times 100 = 67\% \]
05. Ans: $G_f = 2.48$, $G_m = 2.30$

Sol: 

$$G_i = \frac{100}{\frac{w_1}{G_1} + \frac{w_2}{G_2} + \frac{w_3}{G_3}}$$

$$= \frac{100}{\frac{60}{2.72} + \frac{35}{2.66} + \frac{5}{1.0}} = 2.48$$

$V_a = 7\%$

\[ V_a = \frac{G_i - G_m}{G_i} \times 100 \]

\[ \Rightarrow 7 = \frac{2.48 - G_m}{2.48} \times 100 \]

$G_m = 2.30$

06. Ans: (c)

Sol: 

CBR (%) = $\frac{P_{2.5}}{P_{st 2.5}} \times 100$

$$= \frac{60.5}{1370} \times 100 = 4.4\%$$

CBR (%) = $\frac{P_5}{P_{st 5}} \times 100$

$$= \frac{80.5}{2055} \times 100 = 3.92\%$$

Adopt higher one.

\[ \therefore \text{CBR}(\%) = 4.4 \]

01. Ans: 34.22 msa

Sol: Assume lane distribution factor, $F = 1$

\[ A = 1000 \left( 1 + \frac{7.5}{100} \right)^5 = 1435.6 \text{ CVPD} \]

\[ N = \frac{365 \left[ (1 + 0.075)^5 - 1 \right] \times 1435.6 \times 2.5 \times 1}{0.075} \]

= 34.22 msa

02. Ans: (c)

Sol: 

\[ N = \frac{365 \left[ (1 + r)^n - 1 \right] \times A \times D \times F}{r} \]

Assume $F = 0.75$

\[ A = P(1+r)^n \]

\[ = 1000 \left( 1 + 0.1 \right)^5 = 1610.51 \]

\[ N = \frac{365 \left[ (1 + 0.1)^5 - 1 \right] \times 1610.51 \times 3 \times 0.75}{0.1} \]

= 42.02 msa

03. Ans: (b)

Sol: 

\[ N = N_1 + N_2 \]

\[ = \frac{365 \left[ (1 + r)^n - 1 \right] \times A \times D \times F}{r} \]

\[ N = \frac{365 \left[ (1 + 0.075)^{10} - 1 \right] \times [2000 \times 5 + 200 \times 6]}{0.075} \]

= 57.8 msa
04. Ans: $F = 3.74$, $N = 25.86$ msa

Sol:

<table>
<thead>
<tr>
<th>S.No</th>
<th>Wheel load</th>
<th>% Total Traffic (Ni)</th>
<th>EF [Fi]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2268</td>
<td>25</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>2722</td>
<td>12</td>
<td>2.07</td>
</tr>
<tr>
<td>3</td>
<td>3175</td>
<td>9</td>
<td>3.84</td>
</tr>
<tr>
<td>4</td>
<td>3629</td>
<td>6</td>
<td>6.55</td>
</tr>
<tr>
<td>5</td>
<td>4082</td>
<td>4</td>
<td>10.49</td>
</tr>
<tr>
<td>6</td>
<td>4536</td>
<td>2</td>
<td>16</td>
</tr>
<tr>
<td>7</td>
<td>4490</td>
<td>1</td>
<td>23.43</td>
</tr>
</tbody>
</table>

$$\Sigma N_i = 59\%$$

$$\Sigma EF = \left(\frac{Actual load}{Standard load}\right)^4$$

(1) \(EF_1 = \left(\frac{2268}{2268}\right)^4 = 1\)

(2) \(EF_2 = \left(\frac{2722}{2268}\right)^4 = 2.07\) …

$$VDF = \frac{\Sigma N_i f_i}{\Sigma N_i} = \frac{25 \times 1 + 12 \times 2.07 + 9 \times 3.84 + 6 \times 6.55 + 4 \times 10.49 + 2 \times 16 + 1 \times 23.23}{59}$$

$$VDF = 3.74$$

Given \(LDF = 0.4\)

Total Traffic = 1860 cv/day

\[ \therefore \text{Total commercial traffic (A)} = 1860 \times \frac{59}{100} = 1094.4 \text{ cv/day} \]

\[ N = \frac{365 \left( \left(1 + 0.075 \right)^{20} - 1 \right) \left(1094.4 \times 0.4 \times 3.74 \right)}{0.075} \]

\[ N = 25.94 \times 10^6 \text{ csa} = 25.87 \text{ msa} \]
05. Ans: 1.26

Sol:

Equivalent axle load and vehicle damage factor (VDF)

<table>
<thead>
<tr>
<th>Axle load</th>
<th>Number of load repetition</th>
<th>Equivalent factor</th>
<th>Equivalent axle load</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td>1000</td>
<td>(80/80)^4 = 1</td>
<td>1000</td>
</tr>
<tr>
<td>160</td>
<td>100</td>
<td>(160/80)^4 = 16</td>
<td>1600</td>
</tr>
<tr>
<td>40</td>
<td>1000</td>
<td>(40/80)^4 = 0.0625</td>
<td>62.5</td>
</tr>
</tbody>
</table>

\[
\text{VDF} = \frac{(1000 \times 1) + (100 \times 16) + (1000 \times 0.0625)}{1000 + 100 + 1000} = 1.26
\]

\[
\text{The equivalent axle load} = 2662.5 \text{ kN}
\]

01. Ans: (a)

Sol: \[ L = \frac{\delta'}{\alpha(t_2 - t_1)} = \frac{2.5}{10 \times 10^{-6} (45 - 10)} = 3571.42 \text{cm} \]

= 35.71 m

(\( \delta' = 50\% \) of gap expansion joint)

02. Ans: (a)

Sol: \[
\sigma_{w(c)} = \frac{C_E \alpha t}{2} = \frac{0.92 \times 3 \times 10^5 \times 10 \times 10^{-6} \times 16.2}{2} = 22.35 \text{ kg/cm}^2
\]

03. Ans: (d)

Sol: \[
l = \left[ \frac{Eh^3}{12k(1-\mu^2)} \right]^{\frac{1}{4}} = \left[ \frac{3 \times 10^5 \times 20^3}{12 \times 8(1 - 0.15^2)} \right]^{\frac{1}{4}} = 71.1 \text{ cm}
\]

\[
\sigma_{w(c)} = \frac{E \alpha t}{3(1-\mu) \sqrt{l}} = \frac{3 \times 10^5 \times 10 \times 10^{-6} \times 16.2}{3(1 - 0.15) \sqrt{71.1}} = 8.75 \text{ kg/cm}^2
\]

04. Ans: (a)

Sol: \[
A_s = \frac{B hf \tau_c}{\sigma s \times 100} = \frac{1}{2} \times 7.2 \times 18 \times 1.5 \times 2400 \times 1700 \times 100
\]
Chapter- 16
Traffic Engineering

01 Ans: (a)
Sol: Time mean speed
\[ V_t = \frac{50 + 40 + 60 + 54 + 45}{5} \]
\[ (V_t) = 49.8 \text{ kmph} \]
\[ V_s \rightarrow \text{space mean speed} \]
\[ V = \frac{1}{V_1 + V_2 + V_3 + V_4 + V_5} \]
\[ V = 9.76 \text{ kmph} \]
\[ V_s = V \times n = 9.76 \times 5 = 48.80 \text{ kmph} \]

02 Ans: (a)
Sol:

<table>
<thead>
<tr>
<th>Speed Range (m/s)</th>
<th>Frequency PCU/hr (q)</th>
<th>Mid- pt speed (v)</th>
<th>qv</th>
<th>q/v</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5</td>
<td>1</td>
<td>2.5</td>
<td>2.5</td>
<td>0.4</td>
</tr>
<tr>
<td>7.5</td>
<td>4</td>
<td>7.5</td>
<td>30</td>
<td>0.533</td>
</tr>
<tr>
<td>11.5</td>
<td>0</td>
<td>11.5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>15.5</td>
<td>7</td>
<td>15.5</td>
<td>108.5</td>
<td>0.45</td>
</tr>
</tbody>
</table>

\[ \Sigma q=12 \]
\[ \Sigma qv= 142.0 \]
\[ \Sigma \frac{q}{v} = 1.38 \]

\[ V_t = \frac{\Sigma q \times v}{\Sigma q} = \frac{141}{12} = 11.75 \text{ m/s} \]
\[ V_s = \frac{\Sigma q \times \left(\frac{q}{v}\right)}{\Sigma \left(\frac{q}{v}\right)} = \frac{12}{1.38} = 8.69 \text{ m/s} \]
Always the time mean speed is more than space mean speed \( i.e, V_t > V_s \).

03. Ans: 41.8 & 40.91

Sol:

Speed of vehicle-A \( = \frac{1}{1.2/60} = 50 \text{ kmph} \)

Speed of vehicle-B \( = \frac{1}{1.5/60} = 40 \text{ kmph} \)

Speed of vehicle-C \( = \frac{1}{1.7/60} = 35.3 \text{ kmph} \)

Average travel speed 
\( (V_t) = \frac{50 + 40 + 35.3}{3} = 41.8 \text{ kmph} \)

Space mean speed \( (V_s) = \frac{\sum \left( \frac{1}{V_i} \right)}{n} \)
\( = \frac{1}{50} + \frac{1}{40} + \frac{1}{35.3} \)
\( = 40.91 \text{ kmph} \)

04. Ans: 4000 veh/hr

Sol: Design flow rate \( \frac{q}{pHF} \)

\( PHF = \frac{q}{4(q_{15})} \)

Volume during peak 15 min \( (q_{15}) = 1000 \)

Peak hour volume \( (q) \)
\( = 700 + 812 + 1000 + 635 \)
\( = 3147 \)

\( \therefore \) Design flow rate \( \frac{3147}{4000} \approx 4000 \text{ veh/hr} \)

05.

Sol: Total frequency = 100

\( \% \text{ frequency} = \frac{10}{1000} \times 100 = 1 \)

(i) \( 85^{th} \text{ percentile speed is considered as a safe speed from graph } V_{85} = 65 \text{ kmph} \)

(ii) \( 98^{th} \text{ percentile speed is considered as a design speed from graph } V_{98} = 85 \text{ kmph} \)

(iii) \( 15^{th} \text{ percentile speed is considered as a minimum speed on the highway from graph } V_{15} = 35 \text{ kmph} \)

06. Ans: (c)

Sol: SSD = 0.278 \( V_t + \frac{V^2}{254f} \)
\( = 0.278 \times 65 \times 2.5 + \frac{65^2}{254 \times 0.4} \)
\( = 86.7 \text{ m} \)

\( S = SSD + L = 86.7 + 5 = 91.7 \text{ m} \)
07. Ans: (b)
Sol: \( t = 0.7 \) Assume
\[
\text{SSD} = 0.278 \times Vt = 7.78 \text{ m}
\]
\[
S = \text{SSD} + L = 12.78 \text{ m}
\]
\[
C = \frac{1000 \times V}{S} = 3129
\]
\[
\approx 3130 \text{ veh/hr}
\]

08. Ans: (b)
Sol: \( S = SSD + L = 20 + 6 = 26 \text{ m} \)
\[
C = \frac{1000 \times V}{S} = \frac{1000 \times 40}{26} = 1538 \text{ veh/hr/lane}
\]

09. Ans: (c)
Sol:
Given standard deviation (SD) = 8.8 kmph
mean speed \( x = 33 \text{ kmph} \)
Coefficient of variation = \( \frac{\text{SD}}{x} = \frac{8.8}{33} = 0.2666 \)

10. Ans: (b)
Sol: \( q = uk \)
\[
U = U_{sf} \left[ 1 - \frac{k}{k_j} \right]
\]
\[
\therefore q = U_{sf} \left[ 1 - \frac{k}{k_j} \right] k = U_{sf} \left[ k - \frac{k^2}{k_j} \right]
\]

11. Ans: (d)
Sol: \( V_{sf} = 80 \text{ kmph} \)
\[
k_j = 100 \text{ veh/km}
\]
\[
q_{\text{max}} = \frac{V_{sf} \times k_j}{4} = \frac{80 \times 100}{4} = 2000 \text{ veh/hr}
\]
V_s = \frac{V_{sf}}{2} \text{ (the speed corresponding to q_max is V_s max) = } \frac{80}{2} = 40 \text{ kmph}

12. Ans: 33 veh/km & 149 veh/km
Sol: q_m = 1700 veh/hr
k_m = \frac{1000}{S} = \frac{1000}{5.5} = 181.81
q_m = \left( \frac{V_m}{2} \right) \left( \frac{k_m}{2} \right)
1700 = \left( \frac{V_m}{2} \right) \left( \frac{181.81}{2} \right)

v_m = 37.40 \text{ kmph}

For q = 1000 veh/hr
\tan \theta = \frac{V_m}{k_m}
v = \frac{37.4}{181.81} \times (181.81 - k)

For normal condition
q = v.k
1000 = \frac{37.4}{181.81} \times (181.81 - k) \times k
4861.23 = (181.81 - k)k
4861.23 = 181.81 k - k^2
k = 149 \text{ veh/km and } k = 32.6 \text{ veh/km}
\approx 33 \text{ veh/km}

13. Ans: 35.7 kmph
Sol: V_{sf} = 50 \text{ kmph}
t_j = 70 \text{ veh/km}
q_max = \frac{V_{sf} \times K_j}{4} = \frac{50 \times 70}{4} = 875 \text{ veh/ hr}
K_j = 20 \text{ veh/km}
\frac{K_j}{V_{sf}} = \frac{K_j - K}{V - 0}
\frac{70}{50} = \frac{70 - 20}{V} \Rightarrow V = 35.7 \text{ kmph}

14. Ans: 1268 veh/hr
Sol:
V_{max} = \frac{30 \text{ kmph}}{K_{max}} = \frac{30}{130 - 30} = 39 \text{ kmph}
K_{max} = 130 \text{ veh/km}
V_{max} = \frac{30}{130 - 30} \times 130
= 39 \text{ kmph}
K_{max} = \left( \frac{V_{max}}{2} \right) \left( \frac{K_{max}}{2} \right)
= \frac{39}{2} \times \frac{130}{2}
= 1268 \text{ veh/hr}
15. Ans: (b)

\[ Q_p = \frac{280 \times w \left( 1 + \frac{e}{w} \left( 1 - \frac{p}{3} \right) \right)}{1 + \frac{w}{L}} \]

Sol:
\[ w = 14 \text{ m}; \quad e = 8.4 \text{ m} \]
\[ L = 35 \text{ m} \]
\[ p = \frac{\text{Crossing traffic}}{\text{Total traffic}} \]
\[ = \frac{1000}{2000} = 0.5 \]
\[ Q_p = \frac{280 \times 14 \left( 1 + \frac{8.4}{14} \left( 1 - \frac{0.5}{3} \right) \right)}{1 + \frac{14}{35}} \]
\[ = 3733.33 \text{ PCU/hr} \]

16. Ans: 2064.10 veh/hr

Sol:
\[ w = 6 \text{ m}; \quad p = 0.5 \]
\[ L = 20 \text{ m}; \quad e = 5.5 \text{ m} \]
\[ Q_p = \frac{280 \times 6 \left( 1 + \frac{5.5}{6} \left( 1 - \frac{0.5}{3} \right) \right)}{1 + \frac{6}{20}} \]
\[ = 2064.10 \text{ veh/hr} \]

17. Ans: 0.8%

Sol: Weaving ratio = \( \frac{\text{weaving traffic}}{\text{total traffic}} \)
\[ \frac{V_{13} + V_{24} + V_{43}}{V_{13} + V_{23} + V_{24} + V_{14} + V_{43} + V_{21}} \]
\[ = \frac{450 + 1090 + 600 + 310}{450 + 200 + 1090 + 412 + 600 + 310} \]
Weaving ratio = 0.80%

18. Ans: (b)

Sol:
\[ y_N = \frac{1000}{2500}; \quad y_{NS} = 0.4 \]
\[ y_S = \frac{700}{2500}; \quad y_{EW} = 0.3 \]
\[ y = y_N + y_{EW} = 0.4 + 0.3 = 0.7 \]
\[ L = 12 \text{ sec} \]
\[ C_o = \frac{1.5L + 5}{1 - y} = \frac{1.5 \times 12 + 5}{1 - 0.7} \]
\[ = 76.7 \text{ sec} \approx 77 \text{ sec} \]

19. Ans: (d)

Sol:
\[ y = 0.5 = y_a + y_b \]
\[ L = 10 \text{ sec} \]
\[ C_o = \frac{1.5L + 5}{1 - y} = \frac{1.5 \times 10 + 5}{1 - 0.5} \]
\[ = 40 \text{ sec} \]

20. Ans: 14.23 /veh, 1540 veh/hr

Sol:
\[ C = S \times \frac{g}{C_o} \]
\[ S \rightarrow \text{Saturation flow} \]
\[ g_i \rightarrow \text{effective green time} \]
\[ C_o \rightarrow \text{Cycle time/Optimum signal cycle length} \]
\[
gi \over \Co \rightarrow \text{Green Ratio}
\]

\[
C = 2800 \times 0.55
\]

\[
= 1540 \text{ veh/hr}
\]

\[
\frac{\Co \left(1 - \frac{gi}{\Co}\right)^2}{2 \left(1 - \frac{V_i}{s}\right)}
\]

\[
d_i = \frac{90 (1 - 0.55)^2}{2 \left(1 - \frac{1000}{2800}\right)} = 14.2 /\text{veh}
\]

21. Ans: (a)
Sol: Average delay at red signal is \[
= \frac{\text{red time}}{2}
= \frac{30}{2}
= 15 \text{ sec}
\]

(or)
Alternative Solution:

From fig:
The average delay = The area between cumulative arrival and cumulative departure
/Total no of vehicles (or) The hatched area in above figure/total number of vehicles
\[
\therefore \text{The average delay}
= \frac{1}{2}(50)(40) - \frac{1}{2}(20)(40)
\]

\[
= \frac{1}{2}(50) - \frac{1}{2}(20) = 25 - 10 = 15 \text{ sec}
\]

22. Ans: (a)
Sol: Critical lane volume on major road is increased to 440 veh/hr/lane those for green
time should be increased for major road and it remains same for minor road.

23. Ans: (a)
Sol: Green Time = 27 sec
Yellow Time = 4 sec
Total lost time, \(t_l\) = Start up lost time
+Clearance lost time
\[
= 2 + 1 = 3 \text{ sec}
\]
Effective green time ; \(g = G + y - t_l\)
\[
= 27 + 4 - 3 = 28 \text{ sec}
\]
Saturation flow rate; \(S = \frac{3600}{2.4}\)
\[
= 1500 \text{ veh/hr}
\]

\(h \rightarrow \text{Time headway}\)
Capacity of lane, \( C = S \times \left( \frac{g_i}{C_o} \right) \)

\[= 1500 \times \left( \frac{28}{60} \right)\]

\[= 700 \text{ veh/hr/lane}\]

24. Ans: (d)

Sol: Distance travelled by bicycle = 5 km

Time of travel, \( t = 40 - 15 = 25 \text{ min} \)

Stop time = 15 min

Speed of bicycle = \( V_b = \frac{5}{25} \) km/min

Let speed of stream is \( V \) km/min

Assume traffic density is the constant on the road (\( K = \text{Constant} \)).

but \( K = \frac{q}{V} \)

During journey relative speed of stream = \( V - V_b \)

\[= \left( V - \frac{5}{25} \right) \] \( \text{Vehicles/min} \)

\[K = \frac{\left( \frac{60}{25} \right)}{\left( V - \frac{5}{25} \right)} \] \( \text{ (1) } \)

During stop (\( V_b = 0 \))

\[K = \frac{\left( \frac{45}{15} \right)}{V} = \frac{45}{15V} \] \( \text{ (2) } \)

Equating (1) & (2)

\[\frac{\left( \frac{60}{25} \right)}{\left( V - \frac{5}{25} \right)} = \frac{\left( \frac{45}{15} \right)}{V} \]

\[0.8 = \left( 1 - \frac{5}{25V} \right) \]

\[0.2 = \frac{5}{25V} \]

\[\Rightarrow V = \frac{5}{25 \times 0.2} \]

\[\Rightarrow V = 1 \text{ km/min} \]

\[V = 60 \text{ km/hr} \]

25. Ans: 2133.33 veh/hr

Sol: \( V = 80 - 0.75 \) K

\[V_{\text{max}} \text{ occur, when } K = 0 \]

\[V_{\text{max}} = 80 \text{ kmph} \]

\[K_{\text{max}} \text{ occur when } V = 0 \]

\[K_{\text{max}} = \frac{80}{0.75} = 106.67 \text{ veh/km} \]

Capacity of road, \( q = \frac{K_{\text{max}} \times V_{\text{max}}}{4} \)

\[q = \frac{106.67 \times 80}{4} \]

\[q = 2133.33 \text{ veh/hr} \]
26. Ans: (c)

Sol: In R: 2,5 combination is possible 1,3 and 4,6 are not possible

27. Ans:

Sol: Given:
Speed of the vehicle = 60 kmph
Amber duration = 4 sec
Comfortable deceleration = 3 m/sec²
Car length = 4.0 m
Intersection width = 14 m
Longitudinal friction factor = 0.35
Perception reaction time = 1.5 sec

When the vehicle reaches section A, he sees the amber right. Here, two situations are possible.

There are two possibilities

(i) Driver decides to cross intersection:
Total distance to be covered
= SSD + 14 + 4.0

SSD = \left( vt \right) + \frac{v^2}{2gf}

= (16.67 \times 1.5) + \frac{(16.67)^2}{2 \times 9.81 \times 0.35}

= 65.47 m

(ii) He decides to stop the vehicle time taken to stop the vehicle after sighting the amber light.
= Reaction time + time taken to stop the vehicle after application of brakes

= 1.5 + \left( \frac{18}{3} - 0 \right)

= 1.5 + 5.55

= 7.05 sec > 4 sec

Therefore, in both situations, the required duration is greater than the provided amber duration hence the driver’s claim is correct.

28. Ans: 0.1353

Sol: Probability that the gap is greater than 8 sec
P (h ≥ t) = e^{-\lambda t}
λ = rate of arrival per second

= \frac{900}{3600} = 0.25

t = 8 sec

P (h ≥ 8) = e^{-0.25 \times 8}

P (h ≥ 8) = 0.1353
Chapter- 17
Geometric Design of Railway Track

01. Ans: (b)
Sol: Grade compensations on curves:
   For BG: 0.04% per degree of curve
   For MG: 0.03% per degree of curve
   For NG: 0.02% per degree of curve
   Therefore, in the present case, for 4° curve,
   the grade compensation is
   = 0.04 × 4 = 0.16%

03. Ans: (b)
Sol: Ruling gradient in % = \( \frac{1}{250} \times 100 = 0.4\% \)
   Grade compensation at 0.04% per degree of
   Curve = 0.04 × 3 = 0.12%
   Compensated gradient = 0.4 − 0.12
   = 0.28%
   = \( \frac{0.28}{100} = \frac{1}{357} \)

06. Ans: (c)
Sol:
   \( \frac{l^2}{4} = 2rh - h^2 \)
   \( h^2 \) is neglected (being very small)
   \( \therefore h = \frac{l^2}{8r} \)

07. Ans: (a)
Sol:
   Grade compensation = 2 × 0.04 % = 0.08%
   Stipulated ruling gradient = 0.5%
   Steepest gradient = 0.5% – 0.08% = 0.42% = \( \frac{1}{238} \)

08. Ans: (c)
Sol:
   Curve resistance = 0.04% × D°
   = 0.04 × 4 = 0.16%
   Ruling gradient = \( \frac{1}{150} \)
   = \( \frac{1}{150} \times 100 = 0.67\% \)
   Compensated gradient
   = 0.67 − 0.16
   = 0.51%
   = \( \frac{0.51}{100} = \frac{1}{196} \)
10. Ans: 91.26 kmph
Sol: Given, \( D^\circ = 2^\circ \)
\[
R = \frac{1720}{D^\circ} = \frac{1720}{2} = 860 \text{ mm}
\]
The “weighted average” of different trains at different speeds is calculated from the equation
\[
\text{Weighted average} = \frac{n_1 V_1 + n_2 V_2 + n_3 V_3 + n_4 V_4}{n_1 + n_2 + n_3 + n_4}
\]
\[
V = \frac{15 \times 50 + 10 \times 60 + 5 \times 70 + 2 \times 80}{15 + 10 + 5 + 2} = 58.125 \text{ kmph}
\]
\[
e = \frac{GV^2}{127R} = \frac{1.676 \times 58.125^2}{127 \times 860} = 0.0518 \text{ m} = 5.18 \text{ cm}
\]
Theoretical cant = Equilibrium cant + cant deficiency
\[
= 5.18 + 7.60 = 12.78 \text{ cm}
\]
\[
e = \frac{GV^2}{127R} = \frac{1.676 \times V^2}{127 \times 860} = 0.0518 \text{ m} = 5.18 \text{ cm}
\]
\[
V = 91.26 \text{ kmph}
\]
According to railway boards Speed formula
\[
V = 4.35\sqrt{R - 67}
\]
\[
V = 4.35\sqrt{860 - 67} \approx 122.5 \text{ kmph}
\]
Hence maximum permissible speed (i.e lower of the two value) is 91.26 kmph

11. Ans: 86.4 m
Sol: \( e = 12 \text{ cm} \)
\[
V_{\text{max}} = 85 \text{ kmph}
\]
\[
D = 7.6 \text{ cm (BG)}
\]
Length of transition curves maximum of following:

(a) Based on arbitrary gradient of 1 in 720
\[
L = 7.20 \times e = 7.20 \times 12 = 86.4 \text{ cm}
\]

(b) Based on rate of change of cant deficiency
\[
L = 0.073 \times DV_{\text{max}} = 0.073 \times 7.6 \times 85 = 47.158 \text{ cm}
\]

(c) Based on rate of change of super elevation
\[
L = 0.073e V_{\text{max}} = 0.073 \times 12 \times 85 = 74.46 \text{ cm}
\]
\[\therefore \text{Take maximum } L = 86.4 \text{ cm} \]

01. Ans: (a)
Sol: Wind coverage is the time in a year of time during which cross wind component is as minimum as possible.
02. Ans: (a)
Sol: Length of runway under standard condition
= 2100 m
We have to increase 7% for every 300 m elevation above ground so length of runway
= 2100 + \( \frac{7}{100} \times 2100 \)
= 2247 m

03. Ans: (c)
Sol: Runway elevation = 1000 m (above msl)
Airport reference temperature (ART) = 16°C
Airport standard temperature (AST) = standard temperature at msl - 6.5°C for 1 km height above msl
AST = 15 - 6.5 = 8.5°C
Rise in temperature as per ICAO
= 14 ˚C for every 300 m
Correction for elevation (ICAO)
= 486 \times \frac{300}{100} \times \frac{14}{300} = 1.15 \times 486 = 563.1 m
Correction for temperature
= 3.159°C
Temperature @ airport @ 486 m elevation
= 15 - 3.159 = 11.841°C
1% increase in length for 1° above standard temperature. (3.507° - 11.841°) = 23.729°
1% → 1° change
Correction = \( \frac{23.729}{1} \times 2738.964 + 2738.964 \)
= 3388.89 m
Correction for effective gradient
20% ↑ → 1% effective gradient
= 0.75% change
x = 15%
Total runway length = 1.15 \times 3388.89
= 3897.22 m
≃ 4000 m = 4 km

04. Ans: 4 km
Sol: Runway length = 2460 m
Correction for elevation (ICAO)
300 m → 7%
= 486 \times \frac{7}{100} \times 2460 = 2738.964 m

05. Ans: (d)
Sol: The runway length after being corrected for elevation and temperature should further be
increased at the rate of 20% for every 1% of the effective gradient for 0.5%. 10% should be increased.

So runway length after correction of temperature and elevation

\[ = 2845 + 10 \left( \frac{2845}{100} \right) = 3129.5 \approx 3130 \text{ m} \]

**06. Ans: (d)**

**Sol:** Given \( T_m = 40^\circ\text{C} \)

\( T_a = 25^\circ\text{C} \)

\[ \text{ART} = \frac{2T_a + T_m}{3} \]

\[ = \frac{2 \times 25 + 40}{3} \]

\[ = 30^\circ\text{C} \]

**07. Ans: 2102.17 m**

**Sol:** Length of runway = 1640 m

Elevation = 280 m

Reference temperature = 33.5°C

Effective gradient = 0.2%

**Correction for Elevation (ICAO)**

For 300 m – 7% 

\[ 280 \rightarrow x \]

\[ x = 6.53\% \]

Correction = 1640 + \( \frac{6.53}{100} \times 1640 \)

\[ = 1747.15 \text{ m} \]
08. Ans: 0.36 %

Sol:

<table>
<thead>
<tr>
<th>Chainage</th>
<th>Gradient</th>
<th>Elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>–</td>
<td>280 m</td>
</tr>
<tr>
<td>300</td>
<td>+1%</td>
<td>(280 +0.01×300) = 283</td>
</tr>
<tr>
<td>900</td>
<td>-0.5%</td>
<td>283– ( \frac{0.5}{100} ) × 600 = 280</td>
</tr>
<tr>
<td>1500</td>
<td>+0.5</td>
<td>280 + ( \frac{0.5}{100} ) × 690 = 283</td>
</tr>
<tr>
<td>1800</td>
<td>+1</td>
<td>283 +0.01×300 = 286</td>
</tr>
<tr>
<td>2100</td>
<td>-0.5</td>
<td>286 – ( \frac{0.5}{100} ) × 300 = 284.5</td>
</tr>
<tr>
<td>2700</td>
<td>0.4</td>
<td>284.5– ( \frac{0.4}{100} ) × 600 = 282.1</td>
</tr>
<tr>
<td>3000</td>
<td>-0.1</td>
<td>282.1– ( \frac{0.1}{100} ) × 300 = 281.8</td>
</tr>
</tbody>
</table>

Effective gradient = \( \frac{286–280}{1640} \) ×100

= 0.36%

20% → 1%
x → 0.36%
x = 7.2%↑

Total length of runway = 1.072× 2102.17

= 2253.5 m

09. Ans: 400 m

Sol:

(i) Horonjeff’s equation:

\[
R = \frac{0.388 T^2}{0.5 T - S}
\]

\[
= \frac{0.388 \times 17.7^2}{0.5(23) - (6 + \frac{6.62}{2})} = 55.50 m
\]

(ii) Turning radius

\[
R = \frac{V^2}{125 f}
\]

\[
= \frac{80^2}{125 \times 0.13} = 393.85 m
\]

(iii) The minimum radius of sub sonic aircraft is 135 m

:. Turning radius = Maximum of three conditions

= 393.85 m

R ≈ 400 m