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</td>
<td>20</td>
<td>8</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Q</td>
<td>28</td>
<td>19</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>R</td>
<td>12</td>
<td>7</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Weightage factor</td>
<td>0.5</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

\[ \therefore \text{RQP} \]

02. Ans: (a)
Sol:

<table>
<thead>
<tr>
<th>Road</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</td>
<td>300</td>
<td>100</td>
<td>80</td>
<td>30</td>
<td>6</td>
</tr>
<tr>
<td>Q</td>
<td>400</td>
<td>200</td>
<td>90</td>
<td>00</td>
<td>8</td>
</tr>
<tr>
<td>R</td>
<td>500</td>
<td>240</td>
<td>110</td>
<td>70</td>
<td>10</td>
</tr>
<tr>
<td>S</td>
<td>550</td>
<td>248</td>
<td>112</td>
<td>73</td>
<td>12</td>
</tr>
<tr>
<td>Weightage factor</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

\[ \therefore \text{RSPQ} \]

03. Ans: (b)
Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-1, 2nd  Question -pg: 954)
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 = \( \frac{75}{50} = 1.5 \) \( \therefore \) GC = 1.5

The compensated gradient = 6% – 1.5
= 4.5%

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

Chapter- 5
Highway Geometric Design - Sight Distances

01. Ans: (c)
Sol: B.D = 16 m,
f = 0.4
\( \frac{V^2}{254f} = 16 \)
\( \Rightarrow \frac{V^2}{254 \times 0.4} = 16 \)
\( V = 40.3 \) kmph \( \approx \) 40 kmph

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

03. Ans: (b)
Sol: V = 72 kmph, n = 2%,
f = 0.15,
t = 1.5 sec
SSD = 0.278Vt + \( \frac{V^2}{254(f + 0.01n)} \)
= 150 m
04. Ans: (b)
Sol: \( V = 60 \text{ kmph} \)
\[ t = 2.5 \text{ sec}, f = 0.36 \]
\[ 0.278Vt - \frac{V^2}{254(f + 0.01n)} = \frac{6}{5} \]
\[ 0.278 \times 60 \times 2.5 = \frac{6}{5} \left[ \frac{60^2}{254(0.36 + 0.01n)} \right] \]
\[ n = 4.78 \approx 4.8 \]

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

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

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
\[ A = fg = 0.75 \times 9.81 = 7.35 \text{ m/s}^2 \]
During 1st phase, assume driver reaction time 0.5 sec
\[ v_0 = v_1 + \frac{a}{2} (t_1 - t_o) \]
During 3rd phase, deceleration assumed to be uniform
\[ v_1 = \sqrt{v_o^2 + 2aS} = \sqrt{11.18^2 + 2 \times 7.35 \times 27.45} \]
\[ = 22.98 \text{ m/s} = 82.76 \text{ kmph} \]
\[ v_o = 82.76 + \frac{7.35}{2} (0.8 - 0.5) \]
\[ = 83 \text{ kmph} \]

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

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

Intersection + length of car
\[7.5 + 6.1 = 13.6 \text{ m}\]

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

09. Ans: \(T = 7.13 \text{ sec}, V = 138 \text{ kmph}\)

Sol:

\[
\begin{align*}
20/20 & \quad 20/40 \\
\quad \quad & \quad \quad \quad 115 \text{ m} \\
\quad \quad & \quad \quad \quad 230 \text{ m}
\end{align*}
\]

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

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

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

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

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

\[= 138 \text{ kmph}\]

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

\[\text{i.e} \quad 58 \times \frac{5}{18} = 16.11 \text{ m/sec}\]

\[\text{Velocity} = \frac{D}{T}\]

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

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

10. Ans: 142

Sol: For normal driver with 6/6 vision the position of sign post is shown below.

\[\begin{align*}
\text{A} & \quad S_1 = 48 \text{ m} \\
\text{C} & \quad S_2 = ? \\
\text{B} & \quad \text{Start of zone-y}
\end{align*}\]

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

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

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

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

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.

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

The position of sign post is as shown below

\[\begin{align*}
\text{A} & \quad S_1 = 32 \text{ m} \\
\text{C} & \quad S_2 = X = ? \\
\text{B} & \quad \text{Start of zone-y}
\end{align*}\]

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

The distance from modified position of sign post to the start of zone-y (i.e. C’B)

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

11. Ans: 900.79

Sol: 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 = \( d_1 + d_2 + d_3 \)
\( = 0.278V_b t+(0.278V_b T+2s)+0.278 VT \)
\( = 406.74 \text{ m} \)

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: \( V = u + at \)
\( u = 100 \text{ kmph} \)
\( = 27.7 \text{ m/s} \)
\( = 27.7 + 0.8 \times 5 \)
\( V = 31.72 \text{ m/s} \)
\( V^2-u^2 = 2 \times as \)
\( (31.7)^2-(27.7)^2 = 2 \times 0.8 \times S \)
\( S = 148.5 \text{ m} \)
Distance traveled in next 2 sec
\( = 323 - 148.5 \)
\( S = 174.5 \text{ m} \)
Now, \( u = 31.7 \text{ m/s} \)
\( S = ut + \frac{1}{2} at^2 \)
\( 174.5 = (31.7 \times 5) + \left( \frac{1}{2} \times a \times 5^2 \right) \)
\( a = 1.2 \text{ m/sec}^2 \)

05. Ans: (d)
Sol: Distance traveled in overtaking process (\( d_2 \))
\( d_2 = (V_b T + 2s) \quad S_1 = 25 \text{ m} \)
\( = (V_b T + S_1 + S_2) \quad S_2 = 20 \text{ m} \)
\( T = \sqrt{\frac{4s}{a}} = 10.6 \text{ sec} \)
\( d_2 = (0.278 \times 100 \times 10) + (25 + 20) \)
\( = 323 \text{ mm} \)
Common data for Questions 06 & 07

06. Ans: (c)
Sol: $\text{OSD} = d_1 + d_2$

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

07. Ans: (d)
Sol: Desirable length of OZ = 5 OSD

\[
= 5 (d_1 + d_2 + d_3) \\
= 5 \times 460 \\
\approx 2300 \text{ m}
\]

Common data for Questions 01 & 02

01. Ans: (a)
Sol: $e = \frac{V^2}{225 R}$

\[
e = \frac{65^2}{225 \times 600} = 0.031
\]

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

03. Ans: (c)
Sol: $e_{cal} = \frac{V^2}{225 R} = \frac{65^2}{225 \times 125} = 0.15$

\[
e_{cal} > 0.07 \\
\therefore 65 \text{ kmph is not suitable}
\]

\[
0.07 + f = \frac{V^2}{127 R} \rightarrow f = \frac{65^2}{127 \times 125} - 0.07 \\
= 0.196 > 0.15
\]

$V_a$ should be calculated

\[
0.07 + 0.15 = \frac{V_a^2}{127 \times 125} \\
V_a = 59.1 \text{ kmph}
\]

Common data for Questions 04 to 06

04. Ans: (b)
Sol: $e + f = \frac{V^2}{127 R}$

\[
e + 0.15 = \frac{100^2}{127 \times 500} \\
\Rightarrow e = 0.00748 = 0.74\%
\]

05. Ans: (b)
Sol: $f = \frac{V^2}{127 R} = \frac{100^2}{127 \times 500} = 0.157 \approx 0.16$
06. Ans: (c)
Sol: $f = 0$; 
\[ e + 0 = \frac{100^2}{127 \times 500} \]
\[ \Rightarrow e = 15.75\% \]

07. Ans: (a)
Sol: 
\[ e = \frac{V^2}{225R} = \frac{60^2}{225 \times 500} = 0.032 = 3.2\% \]

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

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

11. Ans: (d)
Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-6, 9th Question - pg: 969)

12. Ans: (c)
Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-6, 10th Question - pg: 969)
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: \( L = 180 \text{ m} \quad S = 80 \text{ m} \)

\[ d = \frac{W}{4} = \frac{7}{4} = 1.75 \text{ m} \]

\[ \alpha = \frac{180S}{2 \pi R} = \frac{180 \times 80}{2 \pi \times 360} = 6.36 \]

\[ m = 360 - 360 \cos(6.36) = 2.2 \text{ m} \]

04. Ans: (c)
Sol: \( L = 180 \text{ m} \quad S = 250 \text{ m} \)

\( L < S \)

\[ m = R - R \cos \left( \frac{\alpha}{2} \right) + \frac{S - L}{2} \sin \left( \frac{\alpha}{2} \right) \]

\[ \alpha = \frac{180L}{2 \pi R} = \frac{180 \times 180}{2 \pi \times 360} = 14.32 \]

\[ m = 360 - 360 \cos(14.32) + \frac{250 - 180}{2} \sin(14.32) = 19.85 \text{ m} \]

Common data for Questions 05 & 06

05. Ans: (c)
Sol: SSD = \( 0.278Vt + \frac{V^2}{254f} \)

\[ = (0.278 \times 80 \times 2.4) + \frac{80^2}{254 \times 0.355} \]

\[ = 124.35 \text{ m} \approx 125 \text{ m} \]

06. Ans: (d)
Sol: \( S = 125 \text{ m} \)

\[ d = \frac{W}{4} = \frac{7}{4} = 1.75 \text{ m} \]

\[ \alpha = \frac{180S}{2 \pi (R - d)} = \frac{180 \times 125}{2 \pi (200 - 1.75)} = 18.06 \]
Chapter- 10
Highway Geometric Design
-Transition Curves

Problems on Curve Resistance

01. Let ‘T’ is the original Tractive force

Sol: 
loss of tractive force = T(1–cosθ)
= T(1–cos45°)
Ratio of loss of Tractive force to original is
= 0.243

02. Curve resistance

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

03. Curve resistance

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)  
\[ L = \frac{eN}{2} \left( W + W_e \right) \]  
\[ = \frac{0.0316 \times 150}{2} \times 7 = 16.59 \text{ m} \]  
Considering terrain  
\[ L = \frac{2.7 V^2}{R} = \frac{2.7 \times 80^2}{900} = 19.2 \text{ m} \]  
\[ \therefore \text{Length of T.C} = 23.7 \text{ m} \]  

05. Ans: (c)  
Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-9, 9th Question - pg: 977)  

06. Ans: (c)  
Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-9, 10th Question - pg: 977)  

07. Ans: (a)  
Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-9, 11th Question - pg: 977)
Common data for Q 04 & 05

04. Ans: (c)
Sol: \( N = \frac{1}{25} \left( -\frac{1}{50} \right) = 0.06 = 6\% \)

\( S = 180 \text{ m} \)

Take \( L > \text{SSD} \)

\[ L = \frac{NS^2}{4.40} = \frac{0.06 \times 180^2}{4.4} = 441.8 \text{ m} \]

\( \approx 442 \text{ m} \)

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 \( L > \text{OSD} \)

\[ L = \frac{NS^2}{9.6} = \frac{0.0183 \times 470^2}{9.6} = 421.09 \text{ m} \]

421.09 < 470

Take \( L < \text{OSD} \)

\[ L = 2S - \frac{9.6}{N} = 2 \times 470 - \frac{9.6}{0.0183} \]

= 406.66 m

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

08. Ans: (c)
Sol: Take \( L \geq \text{OSD} \)

\[ L = \frac{NS^2}{9.6} = \frac{0.018 \times 500^2}{9.6} = 468.75 \text{ m} < 500 \text{ m} \]

Take \( L < \text{OSD} \)

\[ L = 2S - \frac{9.6}{N} = 2 \times 500 - \frac{9.6}{0.018} = 466.67 \text{ m} < 500 \text{ m} \]

\( \therefore \) Length of summit cure,

\( L \approx 467 \text{ m} \)

09. Ans: (c)
Sol: Refer previous ESE-Obj-(Vol-2)
solutions Book (Cha-10, 4th Question - pg: 981)
Chapter- 12
Highway Geometric Design
-Valley Curves

Common data for Questions 01 to 03

01. Ans: (c)
Sol: \( n_1 = \frac{1}{25} \)  \( V = 100 \text{ kmph} \)
\( n_2 = \frac{1}{20} \)  \( C = 0.6 \text{ m/s}^3 \)
SSD = 180 m
\( N = 1 + n_1 - n_2 = n_1 + n_2 \)
\( = \frac{1}{25} + \frac{1}{20} = 0.09 \)
(a) \( L = 0.38 \left( NV^2 \right)^{1/2} \)
\( = 0.38 \left( 0.09 \times 100^2 \right)^{1/2} \)
\( = 114 \)
L > SSD
(b) \( L = \frac{NS^2}{1.5 + (0.035S)} = \frac{0.9 \times 180^2}{1.5 + 0.035(180)} \)
\( = 373.86 \text{ m} \approx 374 \text{ m} \)

02. Ans: (b)
Sol: \( \frac{1.6NV^2}{L} \)
\( = \frac{1.6 \times 0.09 \times 100^2}{374} = 3.85 \)

03. Ans: (a)
Sol: For 9% → 373.86
For 4% → 
\( = \frac{4 \times 374.0}{9} = 166.22 \text{ m} \)
\( \approx 166 \)

Chapter- 13
Highway Materials and Testing

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

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

04.
Sol: Total weight = 825 + 1200 + 325 + 150 + 100
\( = 2600 \text{ gm} \)
% wt of material:
\( A_1 \rightarrow \frac{825}{2600} \times 100 = 31.7\% \)
\( A_2 \rightarrow \frac{1200}{2600} \times 100 = 46.15\% \)
05. Ans: $G_f = 2.48$, $G_m = 2.30$

Sol: 
\[
G_f = \frac{100}{w_1 + \frac{w_2}{G_2} + \frac{w_3}{G_3} + \frac{w_4}{G_4} + \frac{w_5}{G_5}}
\]
\[
= \frac{100}{\frac{60}{2.72} + \frac{35}{2.66} + \frac{5}{1.0}} = 2.48
\]

$V_a = 7\%$

\[
V_a = \frac{G_f - G_m}{G_f} \times 100
\]
\[
= \frac{2.48 - 2.30}{2.48} \times 100 = 7\%
\]

$G_m = 2.30$

06. Ans: (c)

Sol: 
\[
CBR (\%) = \frac{P_{25}}{P_{52.5}} \times 100
\]
\[
= \frac{60.5}{1370} \times 100 = 4.4\%
\]

$CBR (\%) = \frac{P_s}{P_{s2.5}} \times 100$
\[
= \frac{80.5}{2055} \times 100 = 3.92\%
\]

Adopt higher one.
\[\therefore\ CBR(%) = 4.4\]

07. Ans: (b)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-12, 4th Question - pg: 986)
Chapter 14
Pavement Design

01. Ans: 34.22 msa
Sol: Assume lane distribution factor, \( F = 1 \)
\[
A = 1000 \left(1 + \frac{7.5}{100}\right)^5 = 1435.6 \text{CVPD}
\]
\[
N = \frac{365 \left[(1 + 0.075)^{15} - 1\right] \times 1435.6 \times 2.5 \times 1}{0.075} = 34.22 \text{ msa}
\]

02. Ans: (c)
Sol: \( N = \frac{A \times D \times F}{r} \)
Assume \( F = 0.75 \)
\[
N = \frac{365 \left[(1 + 0.1)^{15} - 1\right] \times 1610.51 \times 3 \times 0.75}{0.1} = 42.02 \text{ msa}
\]

03. Ans: (b)
Sol: \( N = N_1 + N_2 \)
\[
N = \frac{365 \left[(1 + 0.1)^{10} - 1\right] \times 2000 \times 5 + 200 \times 6}{0.075}
\]
\[
= 57.8 \text{ msa}
\]
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>

\[ \Sigma N_i = 59\% \]

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

1. \( \text{EF}_1 = \left( \frac{2268}{2268} \right)^4 = 1 \)
2. \( \text{EF}_2 = \left( \frac{2722}{2268} \right)^4 = 2.07 \ldots \)

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

\[ \text{VDF} = 3.74 \]

Given \( \text{LDF} = 0.4 \)

Total Traffic = 1860 cv/day

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

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

\[ N = 25.94 \times 10^6 \text{ csa} = 25.87 \text{ msa} \]
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>

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

.: The equivalent axle load = 2662.5 kN

06. Ans: (d)
Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-13, 2nd Question -pg: 1005)

07. And: (d)
Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-13, 6th Question -pg: 1005)

08. And: (b)
Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-13, 11th Question -pg: 1006)

09. And: (d)
Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-13, 15th Question -pg: 1007)

10. And: (a)
Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-13, 30th Question -pg: 1010)
Chapter- 15
Rigid Pavements

01. Ans: (a)
Sol: \[ L = \frac{\delta'}{\alpha(t_2 - t_1)} = \frac{2.5}{2(45 - 10)} \times 10 \times 10^{-6} \times 10 \times 10^{-6} \times 16.2 \times 2 = 3571.42 \text{cm} \]
\[ = 35.71 \text{ m} \]
(\( \delta' = 50\% \) of gap expansion joint)

Common data for Questions 02 & 03

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

03. Ans: (d)
Sol: \[ l = \left[ \frac{Eh^3}{12k(1-\mu^2)} \right]^{1/4} \]
\[ = \left[ \frac{3 \times 10^5 \times 20^3}{12 \times 8(1-0.15^2)} \right]^{1/4} = 71.1 \text{ cm} \]
\[ \sigma_{w(c)} = \frac{E \alpha t}{3(1-\mu)} \sqrt{\frac{a}{l}} \]
\[ = \frac{3 \times 10^5 \times 10 \times 10^{-6} \times 16.2}{3(1-0.15) \times 15} \times \sqrt{15} \times 71.1 \]
\[ = 8.75 \text{ kg/cm}^2 \]

Common data for Questions 04 & 05

04. Ans: (a)
Sol: \[ A_s = \frac{B h f_{rc}}{\sigma_x \times 100} \]
\[ = \frac{1/2 \times 7.2 \times 18 \times 1.5 \times 2400}{1700 \times 100} \]
\[ = 137.22 \text{ cm}^2/\text{m} \]
Spacing \[ = 100 \times \frac{A_s}{A} = 100 \times \frac{\pi \times 10^2}{137.22} \]
\[ = 57.23 \text{ cm} \approx 550 \text{ mm c/c} \]

05. Ans: (b)
Sol: \[ \frac{d \sigma_s}{2 \sigma_b} = \frac{1 \times 1700}{2 \times 24.6} = 34.55 \text{ cm} \approx 35 \text{ cm} \]

Common data for Questions 06 & 07

06. Ans: (c)
Sol: \[ l = \frac{2\sigma_c}{\gamma_c f} = \frac{2 \times 8 \times 10^4}{2400 \times 1.5} = 4.4 \text{ m c/c} \]

07. Ans: (c)
Sol: \[ L = \frac{200 \sigma_s A_s}{B h \gamma_c f} \]
\[ = \frac{200 \times 1200 \times \frac{\pi}{4} \times (10 \times 10^{-1})^2}{3.75 \times 20 \times 2400 \times 1.5} \times \text{no. of bars} \]
\[ = 8.72 \text{ c/c} \]
No. of bars \[ = \frac{\text{width}}{0.3} = \frac{3.75}{0.3} = 12.5 \approx 13 \text{ No’s} \]
08. Ans: (a)
Sol: \( \sigma_f = \frac{\gamma_c f L}{2 \times 10^4} = \frac{2400 \times 4 \times 1.2}{2 \times 10^4} = 0.576 \text{ kg/cm}^2 \)

09. Ans: (b)
Sol: Refer previous ESE-Obj-(Vol-2) solutions
Book (Cha-14, 1\textsuperscript{st} Question -pg: 1016)

10. Ans: (c)
Sol: Refer previous ESE-Obj-(Vol-2) solutions
Book (Cha-14, 5\textsuperscript{th} Question -pg: 1016)

11. Ans: (c)
Sol: Refer previous ESE-Obj-(Vol-2) solutions
Book (Cha-14, 8\textsuperscript{th} Question -pg: 1017)

12. Ans: (d)
Sol: Refer previous ESE-Obj-(Vol-2) solutions
Book (Cha-14, 12\textsuperscript{th} Question -pg: 1017)

13. Ans: (b)
Sol: Refer previous ESE-Obj-(Vol-2) solutions
Book (Cha-14, 24\textsuperscript{th} Question -pg: 1019)

01. Ans: (a)
Sol: Time mean speed
\[
\frac{50 + 40 + 60 + 54 + 45}{5}
\]
\( V_t = 49.8 \text{ kmph} \)

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>
<tr>
<td>( \Sigma q = 12 )</td>
<td>( \Sigma qv = 142.0 )</td>
<td>( \Sigma \frac{q}{v} = 1.38 )</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\[
V_t = \frac{\sum q v}{\sum q} = \frac{141}{12} = 11.75 \text{ m/s}
\]

\[
V_s = \frac{\sum q}{\sum (q/v)} = \frac{12}{1.38} = 8.69 \text{ m/s}
\]

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 kmph

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

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

Average travel speed

\[ (V_t) = \frac{50 + 40 + 35.3}{3} \]

= 41.8 kmph

Space mean speed (V_s) = \( \frac{n}{\sum \left( \frac{1}{v_i} \right)} \)

= \( \frac{3}{\frac{1}{50} + \frac{1}{40} + \frac{1}{35.3}} \)

= 40.91 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

\[ \therefore \text{Design flow rate} = \frac{3147}{3147} \approx 4000 \text{ veh/hr} \]

05.

Sol: Total frequency = 100

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

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

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

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

06. Ans: (c)

Sol: SSD = 0.278Vt + \( \frac{V^2}{254f} \)

\[ = 0.278 \times 65 \times 2.5 + \frac{65^2}{254 \times 0.4} \]

= 86.7 m

S = SSD + L = 86.7 + 5 = 91.7 m

C = \( \frac{1000V}{S} \)

= \( \frac{1000 \times 65}{91.7} \)

= 709 veh/hr/lane
07. Ans: (b)
Sol: \[ t = 0.7 \text{ Assume} \]
\[ SSD = 0.278Vt = 7.78 \text{ m} \]
\[ S = SSD + L = 12.78 \text{ m} \]
\[ C = \frac{1000V}{S} = 3129 \]
\[ \approx 3130 \text{ veh/hr} \]

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

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

10. Ans: (b)
Sol: \( q = uk \)
\[ U = U_s\left[1 - \frac{k}{k_j}\right] \]
\[ \therefore q = U_s\left[1 - \frac{k}{k_j}\right]k = U_s\left[k - \frac{k^2}{k_j}\right] \]
For max traffic flow; \[ \frac{d}{d_k} = 0 \]

11. Ans: (d)
Sol: \( V_{sf} = 80 \text{ kmph} \)
\[ k_j = 100 \text{ veh/km} \]
\[ q_{max} = \frac{V_{sf} \times k_j}{4} = \frac{80 \times 100}{4} = 2000 \text{ veh/hr} \]
\[ V_s = \frac{V_{sf}}{2} \text{ (the speed corresponding to} \]
\[ q_{max} \text{ is} V_{s\ max}) = \frac{80}{2} = 40 \text{ kmph} \]
12. Ans: 33 veh/km & 149 veh/km
   Sol: \( q_m = 1700 \text{ veh/hr} \)
   \[
   k_m = \frac{1000}{S} = \frac{1000}{5.5} = 181.81
   \]
   \[
   q_m = \left( \frac{V_m}{2} \right) \left( \frac{k_m}{2} \right)
   \]
   \[
   1700 = \left( \frac{V_m}{2} \right) \left( \frac{181.81}{2} \right)
   \]
   \[
   V_m = 37.40 \text{ kmph}
   \]
   For \( q = 1000 \text{ veh/hr} \)
   \[
   \tan \theta = \frac{V_m}{k_m}
   \]
   \[
   v = \frac{37.4 \times (181.81 - k)}{181.81}
   \]
   For normal condition
   \[
   q = v.k
   \]
   \[
   1000 = \frac{37.4 \times (181.81 - k) \times k}{181.81}
   \]
   \[
   4861.23 = (181.81 - k)k
   \]
   \[
   4861.23 = 181.81 k - k^2
   \]
   \[
   k = 149 \text{ veh/km and } k = 32.6 \text{ veh/km}
   \]
   \[
   \approx 33 \text{ veh/km}
   \]

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

14. Ans: 1268 veh/hr
   Sol:
   \[
   V_{max} = \frac{30 \text{ kmph}}{(130 - 30)}
   \]
   \[
   K_{max} = \frac{30}{130 - 30} \times 130
   \]
   \[
   = 39 \text{ kmph}
   \]
   \[
   K_{max} = \frac{V_{max}}{2}
   \]
   \[
   \frac{K_{max}}{2} = \frac{39}{2}
   \]
   \[
   \approx 1268 \text{ veh/hr}
   \]

15. Ans: (b)
   Sol: \[ Q_p = \frac{280 \left( 1 + \frac{e}{w} \right) \left( 1 - \frac{p}{3} \right)}{1 + \frac{w}{L}} \]
   \[
   W = 14 \text{ m}; \ e = 8.4 \text{ m}
   \]
   \[
   L = 35 \text{ m}
   \]
   \[
   p = \frac{\text{Crossing traffic}}{\text{Total traffic}} = \frac{1000}{2000} = 0.5
   \]
   \[
   Q_p = \frac{280 \times 14 \left( 1 + \frac{8.4}{14} \right) \left( 1 - \frac{0.5}{3} \right)}{1 + \frac{14}{35}}
   \]
   \[
   = 3733.33 \text{ PCU/hr}
   \]
16. Ans: 2064.10 veh/hr  
Sol: w = 6m; p = 0.5

\[ L = 20 \text{ m} ; \quad e = 5.5 \text{ m} \]

\[ \frac{280 \times 6 \left( \frac{5.5}{6} \right) 1 - 0.5}{1 + \frac{6}{20}} \]

\[ Q_p = 2064.10 \text{ veh/hr} \]

17. Ans: 0.8%  
Sol: Weaving ratio = \frac{\text{weaving traffic}}{\text{total traffic}}

\[ \frac{V_{13} + V_{24} + V_{43}}{V_{13} + V_{23} + V_{14} + V_{24} + V_{43} + V_{21}} \]

\[ = \frac{450 + 1090 + 600 + 310}{450 + 200 + 1090 + 412 + 600 + 310} \]

Weaving ratio = 0.80%

18. Ans: (b)  
Sol: \[ y_N = \frac{1000}{2500} \]

\[ y_{NS} = 0.4 \]

\[ y_S = \frac{700}{2500} \]

\[ y_{NS} = 0.4 \]

\[ y_E = \frac{900}{3000} \]

\[ y_{EW} = 0.3 \]

\[ y_w = \frac{550}{3000} \]

\[ y = y_{NS} + y_{EW} \]

\[ = 0.4 + 0.3 = 0.7 \]

L = 12 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 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 vech, 1540 vech/hr  
Sol: \[ C = S \times \frac{g}{C_o} \]

S → Saturation flow

\[ g_i \rightarrow \text{effective green time} \]

\[ C_o \rightarrow \text{Cycle time/Optimum signal cycle length} \]

\[ \frac{g_i}{C_o} \rightarrow \text{Green Ratio} \]

\[ C = 2800 \times 0.55 \]

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

\[ d_i = \frac{C_o \left( 1 - \frac{g_i}{C_o} \right)^2}{2 \left[ 1 - \frac{V_i}{s} \right]} \]

\[ = \frac{90 \left( 1 - 0.55 \right)^2}{2 \left( 1 - \frac{1000}{2800} \right)} \]

\[ = 14.2 \text{ vech} \]

21. Ans: (a)  
Sol: Average delay at red signal is \( \frac{\text{red time}}{2} \)

\[ = \frac{30}{2} \]

\[ = 15 \text{ sec} \]
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, $t_L = \text{Start up lost time} + \text{Clearance lost time}$
$= 2 + 1 = 3 \text{ sec}$
Effective green time; $g = G + y - t_L$
$= 27 + 4 - 3 = 28 \text{ sec}$
Saturation flow rate; $S = \frac{3600}{h} = \frac{3600}{2.4}$
$= 1500 \text{ veh/hr}$
h $\rightarrow$ 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 = $V_b = \frac{5}{25} \text{ km/min}$
Let speed of stream is $V \text{ km/min}$
Assume traffic density is the constant on the road ($K = \text{Constant}$).
but $K = \frac{q}{V}$
During journey relative speed of stream=$V - V_b$
During stop \((V_b = 0)\)

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

Equating (1) & (2)

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

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

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

\[
\Rightarrow V = \frac{5}{25 \times 0.2} \quad \Rightarrow V = 1 \text{ km/min}
\]

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

25. Ans: 2133.33 veh/hr

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

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

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

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

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

\[
q = 2133.33 \text{ veh/hr}
\]

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 = 3m/sec²
- Car length = 4.0 m
- Intersection width = 14
- Longitudinal friction factor = 0.35
- Perception reaction time = 1.5 sec

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

There are two possibilities
Chapter 17

Geometric Design of Railway Track

28. Ans: 0.1353

Sol: Probability that the gap is greater than 8 sec
\[ P (h \geq t) = e^{-\lambda t} \]
\[ \lambda = \text{rate of arrival per second} \]
\[ = \frac{900}{3600} = 0.25 \]
\[ t = 8 \text{ sec} \]
\[ P (h \geq 8) = e^{-0.25 \times 8} \]
\[ P (h \geq 8) = 0.1353 \]

29. Ans: (a)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-15, 4th Question -pg: 1025)

30. Ans: (c)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-15, 24th Question -pg: 1028)

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
\[ = 0.04 \times 4 = 0.16\% \]
03. Ans: (b)
Sol: Ruling gradient in % = \(\frac{1}{250}\times100 = 0.4\%\)

Grade compensation at 0.04% per degree of Curve = 0.04 \times 3 = 0.12\%
Compensated gradient = 0.4 - 0.12
= 0.28\%
= \frac{0.28}{100} = \frac{1}{357}

06. Ans: (c)
Sol:
From circle property,
\[ \frac{\ell}{2} \cdot \frac{\ell}{2} = h(2r - h) \]
\[ \frac{\ell^2}{4} = 2rh - h^2 \]

\(h^2\) is neglected (being very small)

\[ \therefore h = \frac{\ell^2}{8r} \]

07. Ans: (a)
Sol: Grade compensation = 2 \times 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\% \times D^\circ
= 0.04 \times 4 = 0.16\%

Ruling gradient = \frac{1}{150}

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}
R = 860 mm

The “weighted average” of different trains at different speeds is calculated from the equation

\[ \text{Weighted average} = \frac{n_1V_1 + n_2V_2 + n_3V_3 + n_4V_4}{n_1 + n_2 + n_3 + n_4} \]

\[ V = \frac{15 \times 50 + 10 \times 60 + 5 \times 70 + 2 \times 80}{15 + 10 + 5 + 2} \]

\[ V = 58.125 \text{ kmph} \]

\[ e = \frac{GV^2}{127R} = \frac{1.676 \times 58.125^2}{127 \times 860} \]

\[ = 0.0518 \text{ m} = 5.18 \text{ cm} \]
Chapter- 18
Airport Runway and Taxiway design

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
$L = 7.20 \times e$
$L = 7.20 \times 12 = 86.4\text{cm}$

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

(c) Based on rate of change of super elevation
$L = 0.073e V_{\text{max}}$
$L = 0.073 \times 12 \times 85$
$L = 74.46\text{cm}$
\therefore \text{Take maximum } L = 86.4\text{cm}$
04. Ans: 4 km

Sol: Runway length = 2460 m
Correction for elevation (ICAO)
300 m → 7%
486 → x
x = 11.34%
corrected length after elevation correction

\[ \frac{11.34}{100} \times 2460 + 2460 = 2738.964 \text{ m} \]
correction for temperature

\[ \text{ART} = T_1 + \frac{T_2 - T_1}{3} \]
\[ = 30.2 + \frac{(46.3 - 30.2)}{3} \]
\[ \text{ART} = 35.57^\circ \]
Temperature gradient 1000 – 6.5
486 – x
x = 3.159^\circ
Temperature @ airport @ 486 m elevation
\[ = 15 - 3.159 = 11.841^\circ \]
1% increase in length for 1° above standard temperature. (3.5057° – 11.841°) = 23.729°
1% → 1° change
x → (35.57° – 11.84%)
x = 23.729%
Correction = \[ \frac{23.729}{100} \times 2738.964 + 2738.964 \]
\[ = 3388.89 \text{ m} \]

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 = \[ 1640 + \frac{6.53 \times 1640}{100} \]
\[ = 1747.15 \text{ m} \]

**Correction for temperature (ICAO)**
ART = 33.5°C m

Temperature gradient
1000 m \( \rightarrow \) 6.5°

280 m \( \rightarrow \) x

\[ x = 1.82^\circ \]

Temp @ airport @ 280 m elevation
\[ = 15 - 1.82 \]
\[ = 13.18^\circ \]

1% increase in length for 1° above standard temperature = 33.5° – 13.18°

\[ = 20.32^\circ \]

\[ 1^\circ \uparrow \rightarrow 1\% \uparrow \]

\[ 20.32^\circ \uparrow \rightarrow x \]
\[ x = 20.32\% \]

Correction = \[ \frac{20.32}{100} \times 1747.15 + 1747.15 \]
\[ = 2102.17 \text{ m} \]

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 \times 300 ) = 283</td>
</tr>
<tr>
<td>900</td>
<td>-0.5%</td>
<td>( 283 - \frac{0.5}{100} \times 600 = 280 )</td>
</tr>
<tr>
<td>1500</td>
<td>+0.5</td>
<td>( 280 + \frac{0.5}{100} \times 690 = 283 )</td>
</tr>
<tr>
<td>1800</td>
<td>+1</td>
<td>( 283 + 0.01 \times 300 = 286 )</td>
</tr>
<tr>
<td>2100</td>
<td>-0.5%</td>
<td>( 286 - \frac{0.5}{100} \times 300 = 284.5 )</td>
</tr>
<tr>
<td>2700</td>
<td>0.4</td>
<td>( 284.5 - \frac{0.4}{100} \times 600 = 282.1 )</td>
</tr>
<tr>
<td>3000</td>
<td>-0.1%</td>
<td>( 282.1 - \frac{0.1}{100} \times 300 = 281.8 )</td>
</tr>
</tbody>
</table>

Effective gradient = \( \left( \frac{286 - 280}{1640} \right) \times 100 = 0.36\% \)

20% \( \uparrow \rightarrow 1\% \)

\[ x \rightarrow 0.36\% \]

\[ x = 7.2\% \uparrow \]

Total length of runway = 1.072 \( \times \) 2102.17
\[ = 2253.5 \text{ m} \]
09. Ans: 400 m

Sol:

(i) Horonjeff’s equation:

$$R = \frac{0.388 \times w^2}{0.5T - S}$$

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

(ii) Turning radius

$$R = \frac{V^2}{125f}$$

$$= \frac{80^2}{125 \times 0.13} = 393.85 \text{ m}$$

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

∴ Turning radius = Maximum of three conditions

= 393.85 m

$$R \approx 400 \text{ m}$$