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GATE | PSUs

CIVIL ENGINEERING

Transportation Engineering

(**Text Book** : Theory with worked out Examples and Practice Questions)

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Transportation Engineering

(Solutions for Text Book Practice Questions)

01. Highway Development and Planning

01. Ans: (d)

Sol:

Road	Length (km)	Number of Villages with population			Utility	Utility/km
		< 2000	2000 – 5000	> 5000		
P	20	8	6	1	8×0.5+6×1+1×2 = 12	12/20 = 0.6
Q	28	19	8	4	19 × 0.5 + 8 × 1 + 4×2 = 25.5	25.5/28 =0.91
R	12	7	5	2	7×0.5+5×1+2×2= 12.5	12.5/12=1.04
Weightage factor		0.5	1	2		

∴ RQP

02. Ans: (a)

Sol:

Road Lane	Length (cm)	Number of villages with population ranges				Industrial Product	Utility	Utility/km
		1000-2000	2000-5000	5000-10000	>10000			
P	300	100	80	30	6	200	100×1+80×2+30× 3+6×4+200 =574	574/300 =1.91
Q	400	200	90	00	8	270	200×1+90×2+8×4+270 = 682	682/400 =1.70
R	500	240	110	70	10	315	240×1+110×2+70 ×3+10×4+315 =1025	1025/500 =2.05
S	550	248	112	73	12	335	248×1+112×2+73×3 +12×4+335 =1074	1074/550 =1.95
Weightage factor		1	2	3	4			

∴ RSPQ

04. Highway Geometric Design - Gradients

Common data for Questions 01 & 02

01. Ans: (b)

Sol: Height of crown $= \frac{W}{2n} = \frac{3.5\times1000}{2\times60}$

$= 29.2$ mm

02. Ans: (d)

Sol: Height of crown $= \frac{W}{2n} = \frac{3.5\times1000}{2\times40}$

$= 43.75$ mm

04. Ans: (a)

Sol: $G.C = \frac{30+R}{R}$

$G.C = \frac{30+50}{50} = 1.6$

$\text{Max GC} = \frac{75}{50} = 1.5 \qquad \therefore GC = 1.5$

The compensated gradient = 6% – 1.5

= 4.5%

05. Ans: (a)

Sol: Height of crown $= \frac{W}{2n} = 7.5\,\text{cm}$

$\frac{W}{2n} = 7.5$

$2n = \frac{9\times100}{7.5}$

$n = 60 \Rightarrow 1 \text{ in } 60$

05. Highway Geometric Design – Sight Distance

01. Ans: (c)

Sol: B.D = 16 m,

f = 0.4

$\frac{V^2}{254f} = 16 \Rightarrow \frac{V^2}{254\times0.4} = 16$

V = 40.3 kmph ≈ 40 kmph

02. Ans: (c)

Sol: V = 30 kmph,

f = 0.4

$BD_{down} = 2\,BD_{up}$

$\frac{V^2}{254(f-0.01n)} = \frac{2\times V^2}{254(f+0.01n)}$

f + 0.01 n = 2 f – 0.02n

0.03 n = 0.4

n = 13.33%

03. Ans: (b)

Sol: V = 72 kmph, n = 2%,

f = 0.15,

t = 1.5 sec

$SSD = 0.278\,Vt + \frac{V^2}{254(f+0.01n)} = 150 \text{ m}$

04. Ans: (b)

Sol: V = 60 kmph

t = 2.5 sec ,f = 0.36

$$\frac{0.278\,Vt}{V^2/254(f+0.01n)}=\frac{6}{5}$$

$$0.278\times60\times2.5=\frac{6}{5}\left[\frac{60^2}{254(0.36+0.01n)}\right]$$

$$n = 4.78 \simeq 4.8$$

05. Ans: (c)

Sol: V = 60 kmph, t = 2.5 sec, f = 0.35

$$SSD = 0.278\,Vt+\frac{V^2}{254\,f}$$

$$= 0.278\times60\times2.5+\frac{60^2}{254\times0.35}=82.1\text{ m}$$

SSD for single two way traffic = 2 × SSD

= 2 ×82.1 = 164.2 m

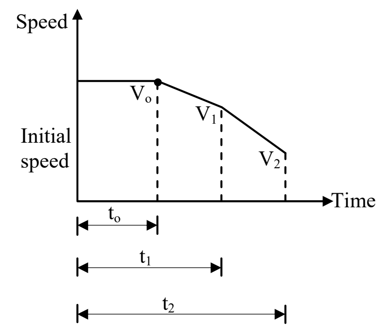
06. Ans: (c)

Sol: ISD = 2 × 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× 9.81 = 7.35 m/s^2

During 1st phase, assume driver reaction time 0.5 sec

$$v_o = v_1+\frac{a}{2}(t_1-t_o)$$

During 3rd phase, deceleration assumed to be uniform

$$v_1=\sqrt{v_2^2+2aS}=\sqrt{11.18^2+2\times7.35\times27.45}$$

= 22.98 m/s = 82.76 kmph

$$v_o=82.76+\frac{7.35}{2}(0.8-0.5)$$

= 83 kmph

08. Ans: (13.6 m)

Sol: $\frac{dv}{dt}=3-0.04v$

A = 3, β = 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 = initial speed = 0

$$=\frac{3(4.25)}{0.04}-\frac{3}{(0.04)^2}(1-e^{-0.04\times4.25})+0$$

$x = 25.62$ m

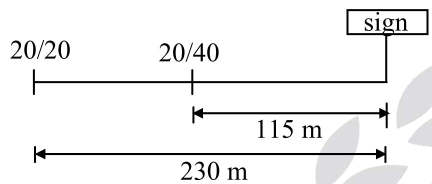
Intersection + length of car

$7.5 + 6.1 = 13.6$ m

$\therefore$ He can clear the intersection

09. Ans: T = 7.13 sec, V = 138 kmph

Sol:



$\frac{20}{20} \rightarrow 230$ m

$\frac{20}{40} \rightarrow x$

$x = 115$ 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 $58 \times \frac{5}{18} = 16.11$ m/sec

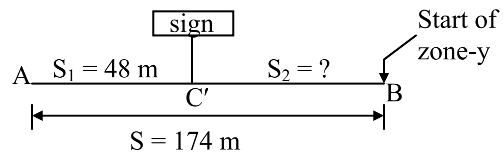
Velocity $= \frac{D}{T}$

$T = \frac{115}{16.11}$

$T = 7.13$ sec

10. Ans: 142

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



$S_2 = 174 - 48 = 126$ m

S_2 = The distance from sign post to the start of zone-y

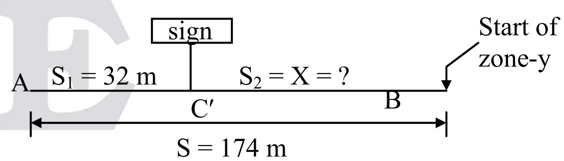
S_1 = Distance traveled by the vehicle during perception – reaction time for 6/6 vision driver

S = 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.

$\therefore$ Modified $S_1 = \frac{6}{9} \times 48 = 32$ m

The position of sign post is as shown below



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

$= 174 - 32 = 142$ m.

11. Refer previous GATE solutions Book (Cha-2, Two marks 9th Question)

06. Highway Geometric Design - Overtaking Sight Distance

Common data for Questions 01, 02 & 03

01. Ans: (c)

Sol: V = 80 kmph, a = 2.5 kmph/sec

V_b = 50 kmph, S = 16 m

t = 2 sec

$$T = \sqrt{\frac{14.4s}{A}} = \sqrt{92.16\,\text{sec}}$$

= 9.6 sec

OSD = $d_1 + d_2$

= $0.278\ V_b\ t + (0.278\ V_b\ T + 2s)$

= 193.24 m

02. Ans: (d)

Sol: OSD = $d_1 + d_2 + d_3$

= $0.278V_bt+(0.278V_bT+2s)+0.278\ VT$

= 406.74 m

03. Ans: (c)

Sol: Since division is there

OSD = $d_1 + d_2$ = 193.24 m

Common data for Questions 04 & 05

04. Ans: (c)

Sol: V = u + at

u = 100 kmph

= 27.7 m/s = 27.7 + 0.8 × 5

V = 31.72 m/s

$V^2 - u^2 = 2 \times as$

$(31.7)^2 - (27.7)^2 = 2 \times 0.8 \times S$

S = 148.5 m

Distance traveled in next 2 sec

= 323 – 148.5

S = 174.5 m

Now, u = 31.7 m/s

$S = ut + ½\ at^2$

$$174.5 = (31.7 \times 5) + \left(\frac{1}{2} \times a \times 5^2\right)$$

a = 1.2 m/sec^2

05. Ans: (d)

Sol: Distance traveled in overtaking process (d_2)

$d_2 = (V_b\ T + 2\ s)$ S_1 = 25 m

$= (V_b\ T + S_1 + S_2)$ S_2 = 20 m

$$T = \sqrt{\frac{4s}{a}} = 10.6\ \text{sec}$$

d_2 = (0.278 × 100 × 10) + (25 + 20)

= 323 m

Common data for Questions 06 & 07

06. Ans: (c)

Sol: OSD = $d_1 + d_2$

V = 22.22 m/s V_b = 16.67 m/s

a = 0.7 m/s^2

S = $(0.7\ V_b + l)$ = 17.67 m

$$T = \sqrt{\frac{4s}{a}} = 10.05\,\text{sec} \qquad t = 2\ \text{sec}$$

OSD = $d_1 + d_2 + d_3$

= $V_b\ t + (V_b\ T + 2s) + VT$

= 236.21 + (22.22 ×10.05)

= 459.521 m ≈ 460 m

07. Ans: (d)

Sol: Desirable length of OZ = 5 OSD

$= 5\ (d_1 + d_2 + d_3)$

$= 5 \times 460$

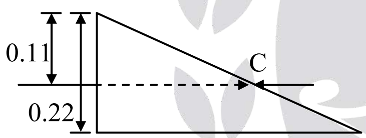
$\simeq 2300$ m

07. Highway Geometric Design - Horizontal Curves

Common data for Questions 01 & 02

01. Ans: (a)

Sol: $e = \dfrac{V^2}{225R} = \dfrac{65^2}{225 \times 600} = 0.031$



$E = e\,w = 0.031 \times 7 = 0.22$ m

w.r.t centre line = 0.11 m

02. Ans: (b)

Sol: w.r.t inner edge ; E = 0.22 m

03. Ans: (c)

Sol: $e_{cal} = \dfrac{V^2}{225R} = \dfrac{65^2}{225 \times 125} = 0.15$

$e_{cal} > 0.07$

$\therefore$ V = 65 kmph is not suitable

$0.07 + f = \dfrac{V^2}{127R} \rightarrow f = \dfrac{65^2}{127 \times 125} - 0.07$

$= 0.196 > 0.15$

V_a should be calculated

$0.07 + 0.15 = \dfrac{V_a^2}{127 \times 125}$

$V_a = 59.1$ kmph

Common data for Questions 04 to 06

04. Ans: (b)

Sol: $e + f = \dfrac{V^2}{127R}$

$e + 0.15 = \dfrac{100^2}{127 \times 500}$

$\Rightarrow e = 0.00748 = 0.74\%$

05. Ans: (b)

Sol: $f = \dfrac{V^2}{127R} = \dfrac{100^2}{127 \times 500} = 0.157 \simeq 0.16$

06. Ans: (c)

Sol: $f = 0$; $e + 0 = \dfrac{100^2}{127 \times 500}$

$\Rightarrow e = 15.75\%$

07. Ans: (a)

Sol: $e = \dfrac{V^2}{225R} = \dfrac{60^2}{225 \times 500} = 0.032 = 3.2\%$

08. Ans: (b)

Sol: $R_{Ruling} = \dfrac{V^2}{127(f + e)}$

$= \dfrac{100^2}{127(0.07 + 0.13)}$

$= 393.7 \text{ m} \approx 395 \text{ m}$

09. Ans: (a)

Sol: b = 2.4 m

h = 4.2 m

$$\frac{b}{2h} = \frac{2.4}{2\times 4.2} = 0.286 > f$$

$$\frac{b}{2h} > f$$

∴ Lateral skidding occur first

10. Ans: (a, d)

Sol: Given: V = 80kmph; H=2b

Critical case for no overturning: $\frac{V^2}{127R} = \frac{b}{2h}$

Where: b = width of vehicle;

h = distance of CG of vehicle from bottom = total height of vehicle(H)/2

$$\frac{b}{2h} = \frac{b}{H}$$

Critical case for no overturning = 0.5

Speed at which the vehicle overturns

$$= \frac{V^2}{127\times 250} = 0.5$$

V = 126 kmph

= 1.57 times allowable speed

Super elevation to be provided

$$= \frac{802}{225\times 250} = 0.113 > 0.07$$

Hence super elevation provided is 7%

08. Horizontal Curves (Extra Widening)

Common data for Questions 01 & 02

01. Ans: (d)

Sol: $e + f = \frac{V^2}{127R}$

$$R_{Ruling} = \frac{76^2}{127\left(\frac{1}{15}+0.15\right)} = 209.9\,m$$

02. Ans: (d)

Sol: $W_e = \frac{n\ell^2}{2R} + \frac{V}{9.5\sqrt{R}}$

$$= \frac{2\times 7^2}{2\times 209} + \frac{76}{9.5\sqrt{209}} = 0.787\ m$$

∴ Total width = 7 + 0.787

= 7.78 m

03. Ans: (c)

Sol: $W_e = \frac{n\ell^2}{2R} + \frac{V}{9.5\sqrt{R}}$

$$= \frac{2\times 8^2}{2\times 300} + \frac{100}{9.5\sqrt{300}} = 0.821\,m$$

04. Ans: (c)

Sol: Given

$W_m = 0.096$

$$\frac{\ell^2}{2R} = 0.096 \Rightarrow R = 226.87\,m$$

$$W_e = W_m + W_{ps} = \frac{n\ell^2}{2R} + \frac{V}{9.5\sqrt{R}}$$

$$= \frac{2\times 6.6^2}{2\times 226.87} + \frac{80}{9.5\sqrt{226.87}}$$

$= 0.75$ m

09. 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: $m = \frac{S^2}{8R} \Rightarrow R = \frac{80^2}{8\times 10} = 80\,m$

Common data for Questions 03 & 04

03. Ans: (c)

Sol: L = 180 m S = 80 m

L > S

$$m = \frac{S^2}{8R} = \frac{80^2}{8\times 360} = 2.22\,m$$

Width of pavement is not indicated

m = R – R cos (α/2)

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

m = 360 – 360 cos (6.36)

= 2.2 m

04. Ans: (c)

Sol: L = 180 m S = 250 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 – 360cos(14.32)

$$+\frac{250-180}{2}\sin(14.32) = 19.85\text{ m}$$

Common data for Questions 05 & 06

05. Ans: (c)

Sol: $SSD = 0.278\,V\,t + \frac{V^2}{254f}$

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

= 124.35 m ≈ 125 m

06. Ans: (d)

Sol: S = 125 m

$$d = \frac{W}{4} = \frac{7}{4} = 1.75\,m$$

$$\frac{\alpha}{2} = \frac{180S}{2\pi(R-d)} = \frac{180\times 125}{2\pi(200-1.75)} = 18.06$$

$$m = R - (R-d)\cos\left(\frac{\alpha}{2}\right) = 11.52\text{ m}$$

$m^1 = m - d$

= 11.52 – 1.75 = 9.77 m

(or)

In approximately

$$m = \frac{S^2}{8R} = 9.76\,m$$

Problems on Curve Resistance

07. Ans: 0.293

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

= 0.293

08.

Sol: Curve resistance = T(1 – cosθ)

= T(1 – cos30°)

= 0.134 T

10. Highway Geometric Design - Transition Curves

Common data for Questions 01 & 02

01. Ans: (d)

Sol: $$L = \frac{0.0215\,V^3}{C\,R}$$

$$= \frac{0.0215 \times 60^3}{0.6 \times 200} = 38.7\,m$$

Considering N value

L = eN (W + W_e) = 0.07 × 100 (7 + 0.2)

= 50.4 m

$$L = \frac{2.7\,V^2}{R} = \frac{2.7 \times 60^2}{200} = 48.6\,m$$

∴ The length of T.C = 50.4 m

(from the 3 values maximum value)

02. Ans: (d)

Sol: $$S = \frac{L^2}{24\,R} = \frac{(50.4)^2}{24 \times 200} = 0.53\,m$$

Common data for Questions 03 & 04

03. Ans: (c)

Sol: $$C = \frac{80}{75 + V} = \frac{80}{75 + 80} = 0.516\,m/sec^3$$

04. Ans: (a)

Sol: Considering 'C' value

$$L = \frac{0.0215\,V^3}{C\,R} = \frac{0.0215 \times 80^3}{0.516 \times 900}$$

= 23.7 m

Considering 'N' value

$$e = \frac{V^2}{225\,R} = \frac{80^2}{225 \times 900} = 0.0316$$

(for mixed traffic)

$$L = \frac{e\,N}{2}(W + W_e)$$

$$= \frac{0.0316 \times 150}{2} \times 7 = 16.59\,m$$

Considering terrain

$$L = \frac{2.7\,V^2}{R} = \frac{2.7 \times 80^2}{900} = 19.2\,m$$

∴ Length of T.C = 23.7 m

11. Highway Geometric Design – Vertical Curves

01. Ans: (b)

Sol: Length of summit parabolic curve,

Assume L > S

$$L = \frac{NS^2}{\left(\sqrt{2H}+\sqrt{2h}\right)^2}$$

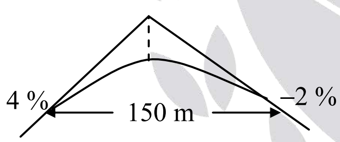
$$= \frac{0.09\times120^2}{\left(\sqrt{2\times1.5}+\sqrt{2\times0.15}\right)^2} = 249\text{ m}$$

02. Ans: (d)

Sol: N = 4 – (–2) = 6%

6% → 150 m

$4\% \rightarrow \frac{4}{6}\times150 = 100\,\text{m}$



03. Ans: (c)

Sol: $N = \frac{1}{50} - \left(-\frac{1}{100}\right) = 0.03 = 3\%$

1 % → 100 m

$3\% \rightarrow \frac{3}{1}\times100 = 300\,\text{m}$

Common data for Q 04 & 05

04. Ans: (c)

Sol: $N = \frac{1}{25} - \left(-\frac{1}{50}\right) = 0.06 = 6\%$

S = 180 m

Take L > SSD

$$L = \frac{NS^2}{4.40} = \frac{0.06\times180^2}{4.4} = 441.8\,\text{m}$$

$\simeq 442$ m

05. Ans: (b)

Sol: 6 % → 442 m

$4\% \rightarrow \frac{4}{6}\times442 = 294.66\,\text{m}$

= 294.66

06. Ans: (a)

07. Ans: (b)

Sol: $N = \frac{1}{100} - \left(\frac{-1}{120}\right) = 0.0183$

Assume L > OSD

$$L = \frac{NS^2}{9.6} = \frac{0.0183\times470^2}{9.6} = 421.09\text{ m}$$

421.09 < 470

Take L < OSD

$$L = 2S - \frac{9.6}{N} = 2\times470 - \frac{9.6}{0.0183}$$

= 406.66 m

08. Ans: (c)

Sol: Take L ≥ OSD

$$L = \frac{NS^2}{9.6}$$

$$= \frac{0.018 \times 500^2}{9.6}$$

$= 468.75$ m < 500 m

Take L < OSD

$$L = 2S - \frac{9.6}{N}$$

$$= 2 \times 500 - \frac{9.6}{0.018}$$

$= 466.67$ m < 500 m

∴ Length of summit cure,

$L \approx 467$ m

12. Highway Geometric Design – Valley Curves

Common data for Questions 01 to 03

01. Ans: (c)

Sol: $-n_1 = \frac{1}{25}$ V = 100 kmph

$n_2 = \frac{1}{20}$ C = 0.6 m/s^3

SSD = 180 m

$$N = |(-n_1 - n_2)| = n_1 + n_2$$

$$= \frac{1}{25} + \frac{1}{20} = 0.09$$

(a) $L = 0.38\,(NV^3)^{1/2}$

$$= 0.38\left(0.09 \times 100^3\right)^{\frac{1}{2}}$$

$= 114$

L > SSD

(b) $$L = \frac{NS^2}{1.5 + (0.035S)} = \frac{0.09 \times 180^2}{1.5 + 0.035(180)}$$

$= 373.86$ m $\simeq 374$ m

02. Ans: (b)

Sol: $$I = \frac{1.6\,NV^2}{L}$$

$$= \frac{1.6 \times 0.09 \times 100^2}{374} = 3.85$$

03. Ans: (a)

Sol: For 9% → 373.86

For 4 % → ?

$$= \frac{4 \times 374.0}{9} = 166.22 \text{ m } \simeq 166$$

04. Ans: (a, b, c, d)

Sol: Length of the valley curve from comfort criteria = $0.38\sqrt{NV^3}$

$= 0.38\sqrt{0.075 \times 80^3} = 74.46$ m say 75 m

Length of the valley curve from headlight sight distance criteria

$$= \frac{NS^2}{1.5 + 0.035S} = \frac{0.075 \times 130^2}{1.5 + 0.035 \times 130} = 209.5 \text{ m say } 210 \text{ m}$$

Impact factor =

$$\frac{1.59NV^2}{L} = \frac{1.59 \times 0.075 \times 80^2}{210} = 3.63$$

13. Highway Materials and Testing

01. Ans: (a)

Sol: $k_1 d_1 = k_2 d_2$

$$(200)\times(30) = (k_2)(75)$$

$$k_2 = k_{\text{of soil}} = 80\,N/cm^3$$

03. Ans: (a)

Sol: $E = \frac{1.18\,Pa}{\delta} = \frac{1.18\times 800\times\left(75/2\right)}{2.5\times 10^{-1}}$

$= 141600\ N/cm^2$

$= 141.6\ kN/cm^2$

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 $\rightarrow \frac{100}{2600}\times 100 = 3.8\%$

$$G_t = \frac{100}{\left(\frac{W_1}{G_1}+\frac{W_2}{G_2}+\frac{W_3}{G_3}+\frac{W_4}{G_4}+\frac{W_5}{G_5}\right)}$$

$$= \frac{100}{\left[\frac{31.7}{2.63}+\frac{46.15}{2.51}+\frac{12.5}{2.46}+\frac{5.7}{2.43}+\frac{3.8}{1.05}\right]}$$

$= 2.41$

$G_m = \frac{1100}{475} = 2.31$

(a) $V_a = \frac{G_t - G_m}{G_t}\times 100 = \frac{2.41-2.31}{2.41}\times 100$

$= 4.15\%$

(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_t =2.48, G_m = 2.30

Sol: $G_t = \frac{100}{\frac{W_1}{G_1}+\frac{W_2}{G_2}+\frac{W_3}{G_3}}$

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

V_a= 7%

$V_a = \frac{G_t - G_m}{G_t}\times 100$

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

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.

$\therefore$ CBR(%) = 4.4

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 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

$$N = \frac{365\left[(1+0.1)^{15} - 1\right] \times 1610.51 \times 3 \times 0.75}{0.1}$$

= 42.02 msa

$A = P(1+r)^n$

$= 1000\,(1+0.1)^5 = 1610.51$

03. Ans: (b)

Sol: $N = N_1 + N_2$

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

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

= 57.8 msa

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

Sol:

S.No	Wheel load	% Total Traffic (Ni)	EF [Fi]
1	2268	25	1
2	2722	12	2.07
3	3175	9	3.84
4	3629	6	6.55
5	4082	4	10.49
6	4536	2	16
7	4490	1	23.43
		ΣN_i = 59%	

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

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

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

$$VDF = \frac{\Sigma N_i f_i}{\Sigma N_i} = \frac{25\times1 + 12\times2.07 + 9\times3.84 + 6\times6.55 + 4\times10.49 + 2\times16 + 1\times23.23}{59}$$

VDF = 3.74

Given LDF = 0.4

Total Traffic = 1860 cv/day

∴ Total commercial traffic (A)

$$= 1860\times\frac{59}{100} = 1094.4 \text{ cv/day}$$

$$N = \frac{365\left((1+0.075)^{20}-1\right)(1094.4\times0.4\times3.74)}{0.075}$$

N = 25.87 × 10^6 csa = 25.87 msa

05. Ans: 266.25 kN, 1.26

Sol: Equivalent axle load and vehicle damage factor (VDF)

Axle load	Number of load repetition	Equivalent factor	Equivalent axle load
80	1000	$(80/80)^4 = 1$	1000
160	100	$(160/80)^4 = 16$	1600
40	1000	$(40/80)^4 = 0.0625$	62.5
			2662.5

∴ The equivalent axle load = 2662.5 kN

$$VDF = \frac{(1000\times1)+(100\times16)+(1000\times0.0625)}{1000+100+1000}$$

= 1.26

15. Rigid Pavements

01. Ans: (a)

Sol: $$L = \frac{\delta'}{\alpha(t_2-t_1)} = \frac{2.5/2}{10\times10^{-6}(45-10)} = 3571.42\text{cm}$$

= 35.71 m

(δ′ = 50% of gap expansion joint)

Common data for Questions 02 & 03

02. Ans: (a)

Sol: $$\sigma_{w(e)} = \frac{C_x E\alpha t}{2}$$

$$= \frac{0.92\times3\times10^5\times10\times10^{-6}\times16.2}{2}$$

= 22.35 kg/cm^2

03. Ans: (d)

Sol: $$l = \left[\frac{Eh^3}{12k(1-\mu^2)}\right]^{1/4}$$

$$= \left[\frac{3\times10^5\times20^3}{12\times8(1-0.15^2)}\right]^{1/4} = 71.1\text{cm}$$

$$\sigma_{w(c)} = \frac{E\alpha t}{3(1-\mu)}\sqrt{\frac{a}{l}}$$

$$= \frac{3\times10^5\times10\times10^{-6}\times16.2}{3(1-0.15)}\times\sqrt{\frac{15}{71.1}}$$

= 8.75 kg/cm^2

Common data for Questions 04 & 05

04. Ans: (a)

Sol: $$A_s = \frac{B\,h\,f\,r_c}{\sigma_s\times100} = \frac{\frac{1}{2}\times7.2\times18\times1.5\times2400}{1700\times100}$$

=137.22 cm^2/m

$$\text{Spacing} = \frac{100\times A}{A_s} = \frac{100\times\left(\frac{\pi}{4}\times10^2\right)}{137.22}$$

= 57.23 cm ≃ 550mm c/c

05. Ans: (b)

Sol: $$L = \frac{d\sigma_s}{2\sigma_b} = \frac{1\times1700}{2\times24.6} = 34.55\text{cm} \simeq 35\text{ cm}$$

Common data for Questions 06 & 07

06. Ans: (c)

Sol: $L = \frac{2\sigma_c}{\gamma_c f} = \frac{2\times 0.8\times 10^4}{2400\times 1.5} = 4.4\,m\,c/c$

07. Ans: (c)

Sol: $L = \frac{200\,\sigma_s A_s}{B\,h\,\gamma_c\,f}$

$= \frac{200\times 1200\times \frac{\pi}{4}\times (10\times 10^{-1})^2}{3.75\times 20\times 2400\times 1.5}\times$ no. of bars

= 8.72 c/c

No. of bars $= \frac{\text{width}}{0.3} = \frac{3.75}{0.3} = 12.5 \simeq 13$ No's

08. Ans: (a)

Sol: $\sigma_f = \frac{\gamma_c\,f\,L}{2\times 10^4} = \frac{2400\times 4\times 1.2}{2\times 10^4}$

$= 0.576\,kg/cm^2$

16. Traffic Engineering

01. Ans: (a)

Sol: Time mean speed

$= \frac{50+40+60+54+45}{5}$

(V_t) = 49.8 kmph

$V_s \Rightarrow$ space mean speed

$\frac{1}{V} = \frac{1}{50}+\frac{1}{40}+\frac{1}{60}+\frac{1}{54}+\frac{1}{45}$

V = 9.76

$V_s = V \times n = 9.76 \times 5 = 48.80$ kmph

02. Ans: (a)

Sol:

Speed Range (m/s)	Frequency PCU/hr (q)	Mid-pt speed (v)	qv	q/v
2.5	1	2.5	2.5	0.4
7.5	4	7.5	30	0.533
11.5	0	11.5	0	0
15.5	7	15.5	108.5	0.45
	Σq=12		Σqv= 142.0	$\Sigma\frac{q}{v}$ 1.38

$V_t = \frac{\sum q\,v}{\sum q} = \frac{141}{12} = 11.75\,m/s$

$V_s = \frac{\sum q}{\sum (q/v)} = \frac{12}{1.38} = 8.69\,m/s$

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 $(V_s) = \dfrac{n}{\sum\left(\dfrac{1}{v_i}\right)}$

$= \dfrac{3}{\dfrac{1}{50}+\dfrac{1}{40}+\dfrac{1}{35.3}}$

= 40.91 kmph

04. Ans: 4000 veh/hr

Sol: Design flow rate $= \dfrac{q}{pHF}$

$PHF = \dfrac{q}{4(q_{15})}$

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

Peak hour volume (q)

= 700 + 812 + 1000 + 635

= 3147

$\therefore$ Design flow rate $= \dfrac{3147}{\dfrac{3147}{4000}} \approx 4000$ veh / hr

05.

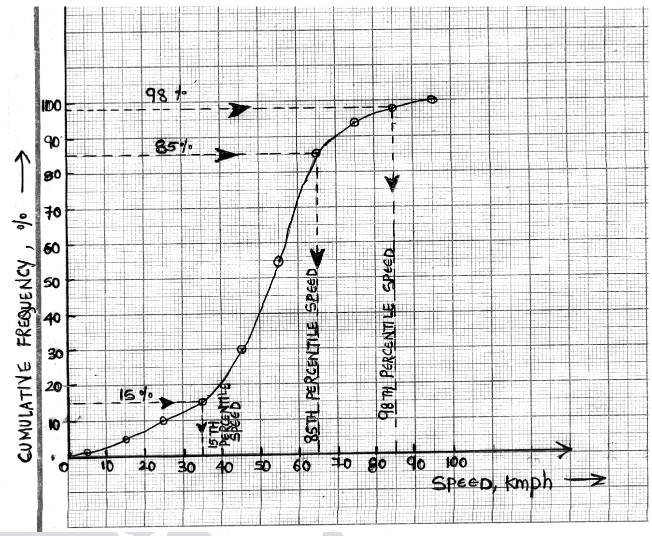
Sol: Total frequency = 100

% frequency $= \dfrac{10}{1000}\times 100 = 1$

(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: $SSD = 0.278\,Vt + \dfrac{V^2}{254\,f}$

$= 0.278\times 65\times 2.5 + \dfrac{65^2}{254\times 0.4}$

= 86.7 m

$S = SSD + L = 86.7 + 5 = 91.7\,m$

$C = \dfrac{1000\,V}{S} = \dfrac{1000\times 65}{91.7}$

$\simeq$ 709 veh / hr / lane

07. Ans: (b)

Sol: $t = 0.7$ Assume

$SSD = 0.278\,Vt$ = 7.78 m

$S = SSD + L$ = 12.78 m

$C = \dfrac{1000\,V}{S} = 3129$

$\simeq$ 3130 veh/hr

08. Ans: (b)

Sol: S = SSD + L =20+6 = 26 m

$$C = \frac{1000\,V}{S} = \frac{1000 \times 40}{26} = 1538\,\text{veh/hr/lane}$$

09. Ans: (c)

Sol: Given standard deviation (SD) = 8.8kmph

mean speed $\bar{x}$ = 33kmph

$$\text{Coefficient of variation} = \frac{SD}{\bar{x}} = \frac{8.8}{33}$$

$$= 0.2666$$

10. Ans: (b)

Sol: q = uk

$$U = U_{sf}\left[1 - \frac{k}{k_j}\right]$$

$$\therefore\ q = U_{sf}\left[1 - \frac{k}{k_j}\right]k = U_{sf}\left[k - \frac{k^2}{k_j}\right]$$

For max traffic flow ; $\frac{d_q}{d_k} = 0$

$$\frac{d_q}{d_k} = U_{sf}\left[1 - \frac{2k}{k_j}\right] = 0$$

$$1 - \frac{2k}{k_j} = 0$$

$k_j = 2k$

U_{sf} = 70 km/hr

$$k_j = \frac{1000}{s} = \frac{1000}{7}$$

$k = k_j/2$

$$q = U_{sf}\left[k - \frac{k^2}{k_j}\right] = U_{sf}\left[k - \frac{k}{2}\right]$$

$$= U_{sf}\left[{k_j}/{2} - {k_j}/{4}\right]$$

$$= U_{sf}\left[{k_j}/{4}\right]$$

$$q = 70 \times \frac{1000}{7} \times \frac{1}{4}$$

= 2500 veh/hr

11. Ans: (d)

Sol: V_{sf} = 80 kmph

k_j = 100 veh /km

$$q_{max} = \frac{V_{sf} \times k_j}{4} = \frac{80 \times 100}{4} = 2000\,\text{veh/hr}$$

$V_s = \frac{V_{sf}}{2}$ (the speed corresponding to q_{max} is $V_{s\ max}$) $= \frac{80}{2} = 40$ kmph

12. Ans: 33 veh/km & 149 veh/km

Sol: q_m = 1700 veh/hr

$$k_m = \frac{1000}{S} = \frac{1000}{5.5} = 181.81$$

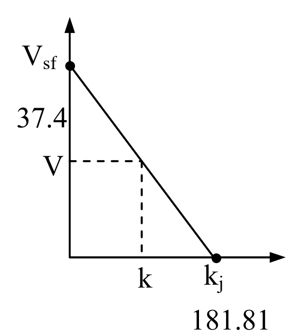
$$q_m = \left(\frac{V_m}{2}\right)\left(\frac{k_m}{2}\right)$$

$$1700 = \left(\frac{V_m}{2}\right)\left(\frac{181.81}{2}\right)$$

v_m = 37.40 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 veh/km and k = 32.6 veh/km

$\simeq$ 33 veh/km

13. Ans: 35.7 kmph

Sol: V_{sf} = 50 kmph

k_j = 70 veh/km

$$q_{max} = \frac{V_{sf} \times K_j}{4} = \frac{50 \times 70}{4} = 875\text{ veh / hr}$$

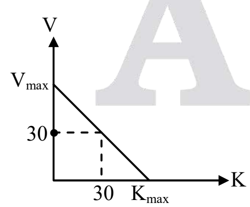
K = 20 veh/km

$$\frac{K_j}{V_{sf}} = \frac{K_j - K}{V - 0}$$

$$\frac{70}{50} = \frac{70 - 20}{V} \Rightarrow V = 35.7\text{ kmph}$$

14. Ans: 1268 veh/hr

Sol:



$$\frac{V_{max}}{K_{max}} = \frac{30\text{kmph}}{(130 - 30)}$$

K_{max} = 130 veh/km

$$V_{max} = \frac{30}{130 - 30} \times 130 = 39\text{ kmph}$$

$$Q_{max} = \left(\frac{V_{max}}{2}\right)\left(\frac{K_{max}}{2}\right)$$

$$= \frac{39}{2} \times \frac{130}{2} \simeq 1268\text{ veh/hr}$$

15. Ans: (b)

Sol: $$Q_p = \frac{280\,w\left(1 + \frac{e}{w}\right)\left(1 - \frac{p}{3}\right)}{1 + w/L}$$

w = 14 m; e = 8.4 m

L = 35 m

$$p = \frac{\text{Crossing traffic}}{\text{Total traffic}}$$

$$= \frac{1000}{2000} = 0.5$$

$$Q_p = \frac{280 \times 14\left(1 + \frac{8.4}{14}\right)\left(1 - \frac{0.5}{3}\right)}{1 + 14/35}$$

= 3733.33 PCU/hr

16. Ans: 2064.10 veh/hr

Sol:

w = 6m ; p = 0.5

L = 20 m ; e = 5.5 m

$$= \frac{280 \times 6\left[1 + \frac{5.5}{6}\right]\left[1 - \frac{0.5}{3}\right]}{1 + \frac{6}{20}}$$

Q_p = 2064.10 veh / hr

17. Ans: 0.8%

Sol:

$$\text{Weaving ratio} = \frac{\text{weaving traffic}}{\text{total traffic}}$$

$$= \frac{V_{13} + V_{24} + V_{43}}{V_{13} + V_{23} + V_{24} + V_{14} + V_{43} + V_{21}}$$

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

Weaving ratio = 0.80%

18. Ans: (b)

Sol:

$$\left.\begin{matrix} y_N = \dfrac{1000}{2500} \\ y_S = \dfrac{700}{2500} \end{matrix}\right\} y_{NS} = 0.4$$

$$\left.\begin{matrix} y_E = \dfrac{900}{3000} \\ y_w = \dfrac{550}{3000} \end{matrix}\right\} y_{EW} = 0.3$$

$y = y_{NS} + y_{EW}$

$= 0.4 + 0.3 = 0.7$

L = 12 sec

$$C_o = \frac{1.5L + 5}{1 - y} = \frac{1.5 \times 12 + 5}{1 - 0.7}$$

= 76.7 sec ≈ 77 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 /veh , 1540 veh/hr

Sol: $C = S \times \dfrac{g}{C_o}$

S → Saturation flow

g_i → effective green time

C_o → Cycle time/Optimum signal cycle length

$\dfrac{g_i}{C_o}$ → Green Ratio

C = 2800 × 0.55 = 1540 veh/hr

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

$$= \frac{\dfrac{90}{2}(1 - 0.55)^2}{1 - \dfrac{1000}{2800}} = 14.23 \text{ /veh}$$

21. Ans: (a)

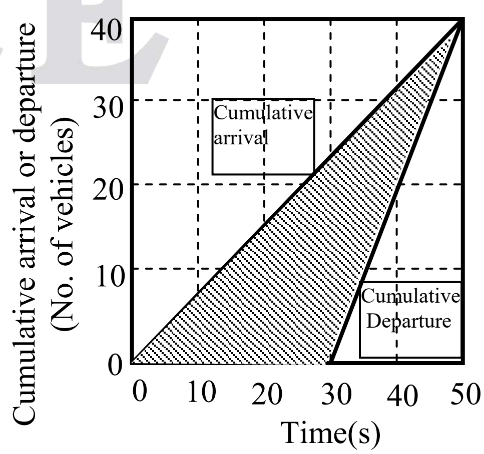
Sol: Average delay at red signal is $= \dfrac{\text{red time}}{2}$

$= \dfrac{30}{2}$

= 15 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

$\therefore$ The average delay

$$= \frac{\frac{1}{2}(50)(40) - \frac{1}{2}(20)(40)}{40}$$

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

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 sec

Effective green time ; $g = G + y - t_L$ = 27 + 4 −3 = 28 sec

Saturation flow rate; $S = \frac{3600}{h} = \frac{3600}{2.4}$ = 1500 veh/hr

h → Time headway

Capacity of lane, $C = S \times \left(\frac{g_i}{C_o}\right)$

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

= 700 veh/hr/lane

24. Ans: (d)

Sol: Distance travelled by bicycle = 5 km

Time of travel, t = 40 – 15 = 25 min

Stop time = 15 min

Speed of bicycle = $V_b = \frac{5}{25}\,\text{km/min}$

Let speed of stream is V km/min

Assume traffic density is the constant on the road (K = Constant).

but $K = \frac{q}{V}$

During journey relative speed of stream= $V - V_b$

$= \left(V - \frac{5}{25}\right)$

$$K = \frac{\left(\frac{60}{25}\right)\text{Vechicles/min}}{\left(V - \frac{5}{25}\right)} \quad \ldots\ldots(1)$$

During stop ($V_b = 0$)

$$K = \frac{\left(\frac{45}{15}\right)\text{Vehicles/min}}{V} = \frac{45}{15V} \quad \ldots\ldots(2)$$

Equating (1) & (2)

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

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

$$0.2 = \frac{5}{25V}$$

$$\Rightarrow V = \frac{5}{25 \times 0.2}$$

$\Rightarrow$ V = 1 km/min

V = 60 km/hr

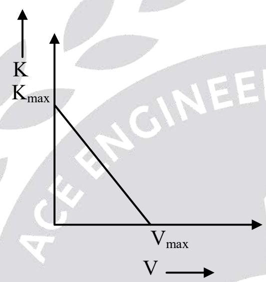
25. Ans: 2133.33 veh/hr

Sol: V = 80 – 0.75 K

V_{max} occur, when K = 0

V_{max} = 80 kmph

K_{max} occur when V = 0



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

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

$$q = \frac{106.67 \times 80}{4}$$

q = 2133.33 veh/hr

26. Ans: (c)

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

27. Ans: Drivers Claim was Correct

Sol: Given:

Speed of the vehicle = 60 kmph

Amber duration = 4 sec

Comfortable deceleration = 3m/sec^2

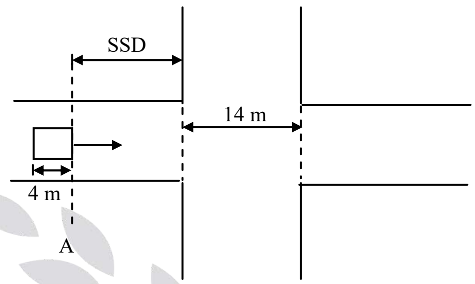
Car length = 4.0 m

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. Hear, two situation are possible.



(i) Driver decides to cross intersection:

Total distance to be covered

= SSD + 14 + 4.0

$$\text{SSD} = (vt) + \frac{v^2}{2gf}$$

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

= 65.47 m

Total distance to be covered

= 65.47 + 14 +4 = 83.47 m

$$\text{Time required} = \frac{\text{distance}}{\text{speed of vehicle}} = \frac{83.47}{16.67}$$

= 5.0 sec > 4 sec

(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

$$= 1.5 + \left(\frac{60 \times \frac{5}{18} - 0}{3}\right)$$

= 1.5 +5.55

= 7.05 sec > 4 sec

Therefore, in both the situation, 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

$P(h \geq t) = e^{-\lambda t}$

λ = rate of arrival per second

$= \frac{900}{3600} = 0.25$

t = 8 sec

$P(h \geq 8) = e^{-0.25 \times 8}$

$P(h \geq 8) = 0.1353$

29. Ans: (a, d)

Sol: In North/south direction.

Flow ratio $q_1 = 900/2100 = 0.428$

In East west direction.

Flow ratio $q_2 = 950/2150 = 0.442$

Cycle time = $\frac{1.5L + 5}{1 - y}$

L = lost time = 2n+R = (2x2)+10= 14sec

$y = q_1 + q_2 = 0.428+0.442= 0.87$

Cycle time = $\frac{1.5 \times 14 + 8}{1 - 0.87} = 200$

Effective green time per cycle = 200 – 14 = 186 sec

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

$= 0.04 \times 4 = 0.16\%$

03. Ans: (b)

Sol: Ruling gradient in % = $\frac{1}{250} \times 100 = 0.4\%$

Grade compensation at 0.04% per degree of Curve = $0.04 \times 3 = 0.12\%$

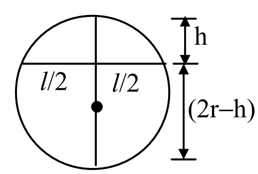
Compensated gradient = 0.4 − 0.12

= 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 $= 0.04\% \times D°$

$= 0.04 \times 4 = 0.16\%$

$$\text{Ruling gradient} = \frac{1}{150}$$

$$= \frac{1}{150} \times 100 = 0.67\%$$

Compensated gradient

$= 0.67 - 0.16$

$= 0.51\%$

$$= \frac{0.51}{100} = \frac{1}{196}$$

10. Ans: 91.26 kmph

Sol: Given, $D° = 2^{\circ}$

$$R = \frac{1720}{D°} = \frac{1720}{2}$$

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 kmph

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

= 0.0518 m

= 5.18 cm

Theoretical cant = Equilibrium cant + cant deficiency

= 5.18 + 7.60

= 12.78 cm

$$e = \frac{GV^2}{127\ R}$$

$$\frac{12.78}{100} = \frac{1.676 \times V^2}{127 \times 860}$$

V = 91.26 kmph

According to railway boards Speed formula

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

$$V = 4.35\sqrt{860 - 67}$$

$$V = 122.5\ \text{kmph}$$

Hence maximum permissible speed

(i.e lower of the two value) is 91.26 kmph

11. Ans: 86.4 m

Sol: e = 12cm

V_{max} = 85 kmph

D = 7.6 cm (BG)

Length of transition curves maximum of following:

(a) Based on arbitrary gradient of 1 in 720

$L = 7.20 \times e$

$L = 7.20 \times 12 = 86.4$cm

(b) Based on rate of change of cant deficiency

$L = 0.073\ DV_{max}$

$L = 0.073 \times 7.6 \times 85$

$L = 47.158cm$

(c) Based on rate of change of super elevation

$L = 0.073e\ V_{max}$

$L = 0.073 \times 12 \times 85$

$L = 74.46cm$

$\therefore$ Take maximum L = 86.4cm

12. (a, b, c, d)

Sol: The permissible speed on a curve in a railway track is minimum

(i) Maximum sanctioned speed

(ii) Speed obtained from Martin's formula which depends on Radius of the curve

(iii) Speed based on Super elevation

(iv) Speed based on length of the transition curve

18. Airport Runway and Taxiway Design

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 ms*l* −6.5°C for 1 km height above ms*l*

AST = 15 −6.5 = 8.5°C

Rise in temperature as per ICAO = 16 −8.5 = 7.5°C

04. Ans: 3388.89 m

Sol: Runway length = 2460 m

Correction for elevation (ICAO)

$300\ m \rightarrow 7\%$

$486 \rightarrow x$

x = 11.34 %

Corrected length after elevation correction

$= \frac{11.34}{100} \times 2460 + 2460$

= 2738.964 m

Correction for temperature

$ART = T_1 + \frac{T_2 - T_1}{3}$

$= 30.2 + \frac{(46.3 - 30.2)}{3}$

ART = 35.57°

Standard Temperature at airport

= 15 – 0.0065h

Temperature @ airport @ 486 m elevation

= 15 – 0.0065 × 486 = 11.841°

Runway length corrected for elevation is further corrected at 1% increase in length for 1° rise above standard temperature.

Rise in temperature = $(35.57^o - 11.841^o)$

= 23.729°

1% → 1^o change

x → 23.729^o

x = 23.729%

$$\text{Correction} = \frac{23.729}{100} \times 2738.964 + 2738.964$$

= 3388.89 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

$$= 2845 + 10\left(\frac{2845}{100}\right) = 3129.5 \simeq 3130 \text{ m}$$

06. Ans: (d)

Sol: Given $T_m = 40^oC$

$T_a = 25^oC$

$$ART = \frac{2T_a + T_m}{3}$$

$$= \frac{2 \times 25 + 40}{3}$$

= 30^oC

07. Ans: 2186.26 m

Sol: Length of runway = 1640 m

Elevation = 280 m

Reference temperature = 33.5°C

Effective gradient = 0.2%

Correction for Elevation (ICAO)

Basic runway length should be increased at the rate of 7% per 300m rise in elevation.

For 300 m – 7 %

280 → x

x = 6.53%

$$\text{correction} = 1640 + \frac{6.53}{100} \times 1640$$

= 1747.15 m

Correction for temperature (ICAO)

Runway length corrected for elevation is further corrected at 1% increase in length for 1^o rise above standard temperature.

ART = 33.5°C m

Temp @ airport @ 280 m elevation

= 15 – 0.0065 × 280 = 13.18°

Raise above standard temperature

= $33.5^o - 13.18^o$

= 20.32^o

1^o ↑ → 1% ↑

20.32^o ↑ → x

x = 20.32%

Correction = $\frac{20.32}{100}\times 1747.15 + 1747.15$

= 2102.17 m

Correction for gradient:

The runway length corrected for elevation and temperature should further be increased by 20% for 1% effective gradient.

For 0.2%, correction = 4%

Runway length corrected to gradient

= 2102.17 + (2102.17 × 4/100) = 2186.26 m

08. What is the effective gradient of the runway site from leveling data given below: **Elevation at the starting point of runway is 280 m.**

End to end of runway (m)	Grade (per cent)
(i) 0 to 300	+1.00
(ii) 300 to 900	– 0.50
(iii) 900 to 1500	+0.50
(iv) 1500 to 1800	+1.00
(v) 1800 to 2100	– 0.50
(vi) 2100 to 2700	– 0.40
(vii) 2700 to 3000	– 0.10

08. Ans: 0.2 %

Sol:

Chainage	Gradient	Elevation
0	–	280 m
300	+1%	(280 +0.01×300) = 283
900	–0.5%	$283 - \frac{0.5}{100}\times 600 = 280$
1500	+0.5	$280 + \frac{0.5}{100}\times 600 = 283$
1800	+1	283 + 0.01×300 = 286
2100	–0.5	$286 - \frac{0.5}{100}\times 300 = 284.5$
2700	–0.4	$284.5 - \frac{0.4}{100}\times 600 = 282.1$
3000	–0.1	$282.1 - \frac{0.1}{100}\times 300 = 281.8$

Effective gradient = maximum difference in elevation between highest and lowest point of runway divided by total length of runway

$$= \left(\frac{286-280}{3000}\right)\times 100 = 0.2\%$$

09. Ans: 400 m

Sol:

(i) Horonjeff's equation:

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

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

(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

$\therefore$ Turning radius = Maximum of three conditions

= 393.85 m

R $\approx$ 400 m