ESE | GATE | PSUs

CIVIL ENGINEERING

TRANSPORTATION ENGINEERING

Text Book : Theory with worked out Examples and Practice Questions

11 Transportation Engineering

(Solutions for Text Book Practice Questions)

01. Highway Development and Planning

01. Ans: (d)

Sol:

Road	Length (km)	Number of 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

03. Ans: (b)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-1, 2nd Question -pg: 968)

04. Highway Geometric Design - Gradients

Common data for Questions 01 & 02

01. Ans: (b)

Sol: Height of crown $= \dfrac{W}{2n} = \dfrac{3.5\times 1000}{2\times 60}$

$= 29.2$ mm

02. Ans: (d)

Sol: Height of crown $= \dfrac{W}{2n} = \dfrac{3.5\times 1000}{2\times 40}$

$= 43.75$ mm

04. Ans: (a)

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

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

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

The compensated gradient = 6% – 1.5

= 4.5%

05. Ans: (a)

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

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

$$2n = \frac{9\times 100}{7.5}$$

$n = 60 \Rightarrow 1$ in 60

Conventional Practice Solutions

01.

Sol: (a) For WBM district road with heavy rainfall

Height of crown with respect to edges $= \dfrac{eW}{2}$

$e = \dfrac{1}{33}$ $\quad W = 3.5$ m

Height of crown w.r.to edges $= \dfrac{1}{33}\times\dfrac{3.5}{2}$

$= 0.053$ m

(b) For state highway of concrete pavement

Height of crown w.r.to edges $= \dfrac{eW}{2}$

$e = \dfrac{1}{50}$ $\quad W = 7$ m

Height of crown w.r.to edges $= \dfrac{1}{50}\times\dfrac{7}{2}$

$= 0.07$ m

05. 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 ≈ 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 m

04. Ans: (b)

Sol: V = 60 kmph

t = 2.5 sec ,f = 0.36

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

$$0.278\times 60\times 2.5 = \frac{6}{5}\left[\frac{60^2}{254(0.36+0.01n)}\right]$$

$n = 4.78 \simeq 4.8$

05. Ans: (c)

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

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

$$= 0.278\times 60\times 2.5 + \frac{60^2}{254\times 0.35} = 82.1 \text{ m}$$

SSD for single two way traffic = 2 × SSD

= 2 ×82.1 = 164.2 m

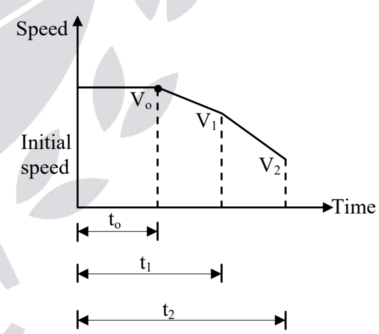
06. Ans: (c)

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

$$v_1 = \sqrt{v_2^2 + 2aS} = \sqrt{11.18^2 + 2 \times 7.35 \times 27.45}$$

$= 22.98$ 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

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

x = 25.62 m

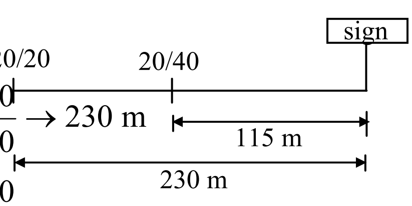
Intersection + length of car

7.5 + 6.1 = 13.6 m

∴ He can clear the intersection

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

Sol:



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

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

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

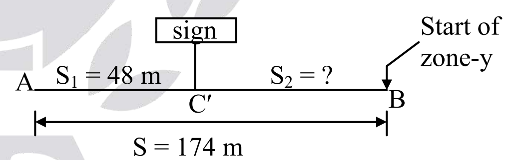
Velocity $= \frac{D}{T}$

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

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

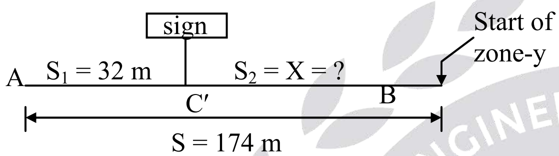
S_1 = Distance traveled by the vehicle during perception – reaction time for 6/6 vision driver

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 $S_1 = \frac{6}{9} \times 48 = 32\,\text{m}$

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. Ans: 900.79

Sol: Refer previous GATE solutions Book (Cha-2, Two marks 9th Question -pg: 821)

12. Ans: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-5, 5th Question -pg: 977)

13. Ans: (c)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-5, 9th Question -pg: 978)

Conventional Practice Solutions

01.

Sol: **(a)** Two way Traffic on a two lane Road:

$$\text{S.S.D} = 0.278\ Vt + \frac{V^2}{254\,f}$$

$$= (0.278 \times 100 \times 2.4) + \frac{100^2}{254 \times 0.35}$$

$$= 66.72 + 112.49$$

$$= 179.2\ \text{m}$$

(b) Two way traffic on a single lane Road

$$\text{S.S.D} = 2 \times \left[0.278Vt + \frac{V^2}{254\,f}\right]$$

$$= 2 \times 179.2$$

$$= 358.4\ \text{m}$$

02.

Sol: Minimum distance Required = SSD_1 + SSD_2

$$= \left(0.278V_1t + \frac{V_1^2}{254\,f\,n}\right) + (0.278V_2t) + \left(\frac{V_2^2}{255\,f\,n}\right)$$

$$= [(0.278 \times 100 \times 2.5) + \left(\frac{100^2}{254 \times 0.33 \times 0.5}\right) +$$

$$[0.278 \times 80 \times 25] + \left(\frac{80^2}{254 \times 0.33 \times 0.5}\right)$$

$$= 69.5 + 238.6 + 55.6 + 152.7 = 516.4\ \text{m}$$

03.

Sol: $SSD_1 = 0.278Vt + \frac{V^2}{254(f+x)}$ ----- (i)

$SSD_2 = 0.278Vt + \frac{V^2}{254(f-x)}$ ----- (ii)

Subtracting 2 equations

$$10 = \frac{V^2}{254(f-x)} - \frac{V^2}{254(f+x)}$$

$$10 = \frac{V^2}{254}\left[\frac{1}{f-x} - \frac{1}{f+x}\right]$$

$$\frac{10\times 254}{V^2} = \frac{(f+x)-(f-x)}{(f^2-x^2)}$$

$$0.706 = \frac{2x}{0.16-x^2}$$

$x = 0.054$

or

$x = 5.54\%$

04.

Sol: (a) $v^2 - u^2 = 2gfs$

$$0 - \left(\frac{60\times 5}{18}\right)^2 = -2\times 9.8\times f\times 5.8$$

$277.78 = 113.796\ f$

$f = 2.44$

(b) $V = \mu + at$

$\mu = -a\,t$

$$\left(60\times\frac{5}{18}\right) = +g\,f\,t$$

$16.67 = 9.81 \times f \times 2$

$f = 0.85$

(c) $S = ut + \frac{1}{2}at^2$

$$7 = \left(60\times\frac{5}{18}\right)\times 1.5 + \frac{1}{2}\times 9.81(-f)\times 1.5^2$$

$7 = 25 - 11.04\ f$

$$f = \frac{18}{11.04} = 1.63$$

05.

Sol: $v^2 - u^2 = 2as$

$$0 - \left(65\times\frac{5}{18}\right)^2 = 2\times a\times 25.5$$

$-326 = 51\ a$

$a = -6.392$

$a = -\,g\,f\,\eta$

$-9.81 \times 0.7 \times \eta = -6.392$

$\eta = 0.93$

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

$= 27.7 + 0.8 \times 5$

$V = 31.72$ 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)

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

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

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

$d_2 = (0.278 \times 100 \times 10) + (25 + 20)$

$= 323$ mm

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 = $d_1 + d_2 + d_3$

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

$= 236.21 + (22.22 \times 10.05)$

$= 459.521$ m

≈ 460 m

07. Ans: (d)

Sol: Desirable length of OZ = 5 OSD

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

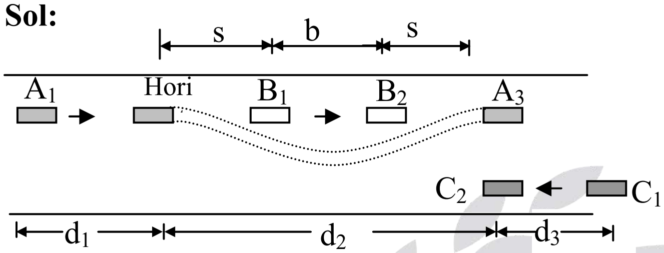
$= 5 \times 460$

$\simeq 2300$ m

Conventional Practice Solutions

01.

Sol:



(i) $d_1 = V_b\, t$

$= 0.278 \times 80 \times 2 = 44.48$ m

(ii) d_2

$$T = \sqrt{\frac{4S}{a}}$$

$S = (0.2\, V_b + l)$

$= (0.2 \times 80 + 6) = 22$ m

$$T = \sqrt{\frac{4 \times 22}{0.92}} = 9.78\,\text{sec}$$

$d_2 = (V_b\, T + 2S)$

$= (80 \times 9.78 \times 0.278) + 44$

$d_2 = 261.5$ m

(iii) $d_3 = (V_a \times T)$

$= 0.278 \times 100 \times 9.78$

$d_3 = 271.9$ m

$OSD = d_1 + d_2 + d_3$

$OSD = 577.88$ m

Desirable length of overtaking zone

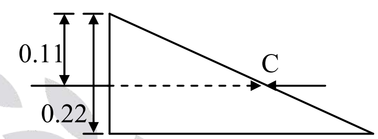
$= 5 \times OSD = 2889.4$ m

07. Highway Geometric Design – Horizontal Curves

Common data for Questions 01 & 02

01. Ans: (a)

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



$E = e\,w = 0.031 \times 7 = 0.22$ 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: $e_{cal} = \dfrac{V^2}{225\,R} = \dfrac{65^2}{225 \times 125} = 0.15$

$e_{cal} > 0.07$

$\therefore$ V = 65 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

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

$V_a = 59.1$ kmph

Common data for Questions 04 to 06

04. Ans: (b)

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

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

$\Rightarrow e = 0.00748 = 0.74\%$

05. Ans: (b)

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

06. Ans: (c)

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

$\Rightarrow e = 15.75\%$

07. Ans: (a)

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

08. Ans: (b)

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

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

$= 393.7$ m ≈ 395 m

09. Ans: (a)

Sol: $b = 2.4$ m

$h = 4.2$ m

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

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

$\therefore$ Lateral skidding occur first

11. Ans: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-6, 9th Question -pg: 984)

12. Ans: (c)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-6, 10th Question -pg: 984)

Conventional Practice Solutions

01.

Sol: (a) $e = \dfrac{V^2}{225R}$

$$= \frac{120^2}{225 \times 450}$$

$e = 0.142$

but $e \ngtr 0.07$

So use $e = 0.07$

(b) $e + f = \dfrac{V^2}{127R}$

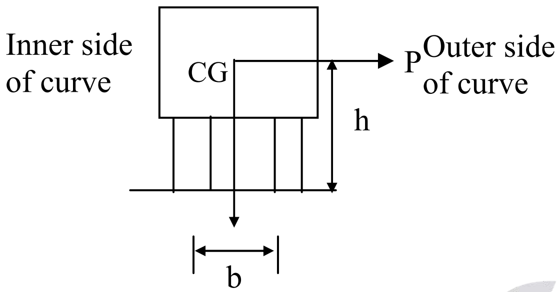
$$V = \sqrt{(e+f) \times 127R}$$

$$= \sqrt{(0.07 + 0.15)127 \times 450}$$

$= 112.1$ kmph

02.

Sol:



To avoid overturning

$$W \times \frac{b}{2} > P \times h$$

$$\frac{b}{2h} > \frac{P}{W}$$

(i) Minimum speed to avoid shading

$$f > \frac{P}{W} \quad \left[\frac{P}{W} = \frac{V^2}{gR}\right]$$

$$f > \frac{V^2}{gR}$$

$$V = \sqrt{f\,g\,R}$$

$$= \sqrt{0.15 \times 9.81 \times 200}$$

$$V < 17.16 \text{ m/sec}$$

(ii) Minimum speed to avoid overturning

$$\frac{b}{2g} > \frac{V^2}{gR}$$

$$V < \sqrt{\frac{bgR}{2h}} = \sqrt{\frac{3.5 \times 9.81 \times 200}{2 \times 1.4}}$$

$$= 49.52 \text{ m/sec}$$

So maximum speed = 17.16 m/sec

08. Horizontal Curves (Extra Widening)

Common data for Questions 01 & 02

01. Ans: (d)

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

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

$$= 209.9 \text{ m}$$

02. Ans: (d)

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

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

$$= 0.787 \text{ m}$$

$\therefore$ Total width = 7 + 0.787

= 7.78 m

03. Ans: (c)

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

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

$$= 0.821 \text{ m}$$

04. Ans: (c)

Sol: Given

$W_m = 0.096$

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

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

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

$= 0.75$ m

Conventional Practice Solutions

01.

Sol: (1) Ruling minimum radius $e + f = \dfrac{V^2}{127R}$

$$R = \frac{V^2}{127(e+f)}$$

$$= \frac{120^2}{127(0.07+0.15)}$$

$R = 515$ m

(2) Extra widening

$$W_e = \frac{\eta\ell^2}{2R} + \frac{V}{9.5\sqrt{R}}$$

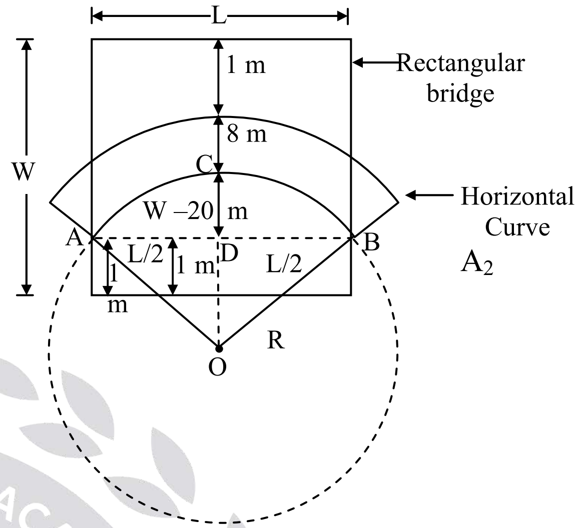
$$= \frac{4\times 6.1^2}{2\times 515} + \frac{120}{9.5\sqrt{515}}$$

$= 0.145 + 0.555$

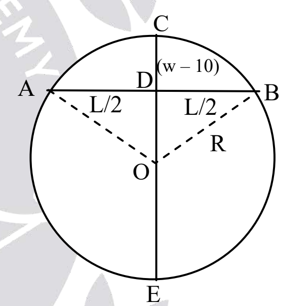
$W_e = 0.7$ m

02.

Sol:



Top View



By property of circle,

(AD) . (DB) = (CD) . (DE)

$$\frac{L}{2}.\frac{L}{2} = (W-10).[(2R-(W-10)]$$

$$\frac{L^2}{4(W-10)} = 2R - (W-10)$$

$$2R = \frac{L^2}{4(W-10)} + W - 10$$

$$R = \frac{L^2}{8(W-10)} + \left(\frac{W-10}{2}\right)$$

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

$m = R - R\cos(\alpha/2)$

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

$m = 360 - 360\cos(6.36)$

$= 2.2$ m

04. Ans: (c)

Sol: L = 180 m S = 250 m

$L < S$

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

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

$m = 360 - 360\cos(14.32)$

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

Common data for Questions 05 & 06

05. Ans: (c)

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

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

$= 124.35$ m ≈ 125 m

06. Ans: (d)

Sol: S = 125 m

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

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

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

$= 11.52$ 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

01.

Sol: Let 'T' is the original Tractive force

loss of tractive force = T(1– cosθ)

$= T(1 - \cos 45^o)$

Ratio of loss of Tractive force to original is

= 0.243

02.

Sol: Curve resistance = T(1 – cosθ)

$= T(1 - \cos 30^o)$

= 0.134 T

03.

Sol: Curve resistance = T(1–cosθ)

$= T(1 - \cos 90^o)$

= 0

Conventional Practice Solutions

01.

Sol: Length of curve < SSD

So set back $= R - (R - d)\cos\left(\frac{\alpha}{2}\right) + \left(\frac{S-L}{2}\right)\sin\left(\frac{\alpha}{2}\right)$

$$\frac{\alpha}{2} = \frac{180L}{2\pi(R-d)}$$

$$\frac{\alpha}{2} = \frac{180\times100}{2\pi\left[500-\left(3.5\times2+\frac{3.5}{2}\right)\right]^2}$$

$$\frac{\alpha}{2} = 5.83^o$$

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

$= 500 - (500 - 8.75)\cos 5.83 + \left(\frac{200-100}{2}\right)\sin 5.83$

= 500 – 488.7 + 5.08

= 16.38 (from centre of food)

Distance from inner edge

= 16.38 – 3 × 3.5 = 5.88 m

10. Highway Geometric Design – Transition Curves

Common data for Questions 01 & 02

01. Ans: (d)

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

$$= \frac{0.0215\times60^3}{0.6\times200} = 38.7\,m$$

Considering N value

$L = eN(W + W_e) = 0.07 \times 100\,(7 + 0.2)$

= 50.4 m

$$L = \frac{2.7\,V^2}{R} = \frac{2.7\times60^2}{200} = 48.6\,m$$

∴ The length of T.C = 50.4 m

(from the 3 values maximum value)

02. Ans: (d)

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

Common data for Questions 03 & 04

03. Ans: (c)

Sol: $C = \frac{80}{75+V} = \frac{80}{75+80}$

$= 0.516\,\text{m/sec}^3$

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

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

(for mixed traffic)

$$L = \frac{eN}{2}(W + W_e)$$

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

Considering terrain

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

$\therefore$ Length of T.C = 23.7 m

05. Ans: (c)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-9, 9th Question -pg: 992)

06. Ans: (c)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-9, 10th Question -pg: 992)

07. Ans: (a)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-9, 11th Question -pg: 992)

Conventional Practice Solutions

01.

Sol: **(i)** Minimum sight distance

$$= 0.278vt + \frac{v^2}{254f}$$

[Assume t = 2.5 sec, & f = 0.4]

$$= (0.278 \times 100 \times 2.5) + \frac{100^2}{254 \times 0.4}$$

= 167.9 m

(ii) Design super elevation

$$e = \frac{V^2}{225R} = \frac{100^2}{225 \times 300}$$

e = 0.148

But $e \not> 0.07$

So limit e to 0.07

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

$$0.07 + f = \frac{100^2}{127 \times 300}$$

$f = 0.192 > 0.15$

So since reduce the speed or increase the radius of the curve.

11. Highway Geometric Design – Vertical Curves

01. Ans: (b)

Sol: Length of summit parabolic curve,

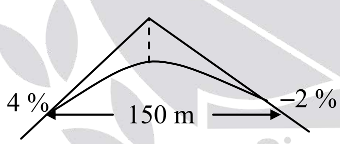
Assume L > S

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

$$= \frac{0.09 \times 120^2}{\left(\sqrt{2 \times 1.5} + \sqrt{2 \times 0.15}\right)^2} = 249 \text{ m}$$

02. Ans: (d)

Sol: $N = 4 - (-2) = 6\%$



$6\% \rightarrow 150$ nm

$4\% \rightarrow \frac{4}{6} \times 150 = 100 \text{ m}$

03. Ans: (c)

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

$1\ \% \rightarrow 100$ m

$3\ \% \rightarrow \frac{3}{1} \times 100 = 300 \text{ m}$

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

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

$\simeq 442$ m

05. Ans: (b)

Sol: $6\ \% \rightarrow 442$ m

$4\ \% \rightarrow \frac{4}{6} \times 442 = 294.66 \text{ m} = 294.66$

06. Ans: (a)

Sol: Refer previous GATE solutions Book (Cha-2.8, Two marks 5th Question -pg: 859)

07. Ans: (b)

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

Assume L > OSD

$$L = \frac{NS^2}{9.6} = \frac{0.0183 \times 470^2}{9.6}$$

$= 421.09$ m

$421.09 < 470$

Take L < OSD

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

$= 406.66$ 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 ≈ 467 m

09. Ans: (c)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-10, 4th Question -pg: 997)

Conventional Practice Solutions

01.

Sol: Length of summit curve

Assume L > SSD

$$L = \frac{NS^2}{4.4}$$

$$N = \frac{1}{50} - \left(-\frac{1}{30}\right) = \frac{80}{1500} = \frac{8}{150}$$

$$L = \frac{8}{150} \times \frac{180^2}{4.4}$$

L = 392.7 m ≈ 400 m

Assumption was correct as L > SSD

(ii) Summit point is at a distance of

$$x = \frac{N_1 L}{N} \quad \text{from start}$$

$$= \frac{0.02 \times 400}{0.0533} = 150.09 \text{ from start}$$

Equation of parabola $= \frac{Nx^2}{2L} = \frac{0.053x^2}{2 \times 400}$

$= 0.00006625\ m^2$

R.L of summit

$= 10 + 150.09 \times 0.02 - (0.00006625 \times 180.09^2)$

= 11.511 m

Vertical distance between point of intersection and curve

$$= \frac{NL}{8} = \frac{0.053 \times 400}{8} = 2.650 \text{ m}$$

Station	x	RL
1	0	10.000
2	20	10.375
3	40	10.694
4	60	10.9615
5	80	11.176
6	100	11.338
7	120	11.446
8	140	11.5015
9	160	11.504
10	180	11.4535
11	200	11.352
12	220	11.1935
13	240	10.984
14	260	10.7215
15	280	10.406
16	300	10.042
17	320	9.616
18	340	9.1415
19	360	8.614
20	380	8.0335
21	400	7.408

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

$= 373.86 \text{ m} \simeq 374 \text{ m}$

02. Ans: (b)

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

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

03. Ans: (a)

Sol: For 9% → 373.86

For 4 % → ?

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

Conventional Practice Solutions

01.

Sol: $N_1 = 0$

$N_2 = -0.033$

$N = N_1 - N_2 = 0.033$

Assume L > SSD

$L = \frac{NS^2}{1.5 + 0.035S}$

$= \frac{0.033 \times 180 \times 180}{1.5 + 0.035 \times 180}$

= 137.1 m

Assume L < SSD

$L = 2S - \frac{1.5 + 0.035S}{N}$

$= 2 \times 180 - \frac{1.5 + 0.035 \times 180}{0.033}$

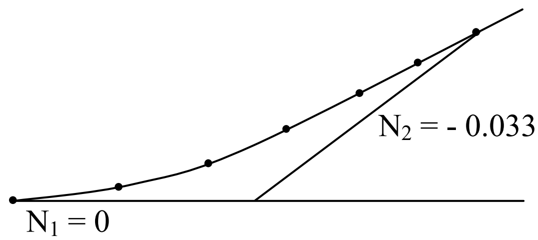
$= 360 - \frac{7.8}{0.033}$

= 360 – 236.4 = 123.6 m

Provide a length of 125 m

$y = \frac{Nx^2}{2L} = \frac{0.033x^2}{2 \times 125} = 0.000132\,x^2$

Station	x	y	RL
1	0	0	10.000
2	25	0.083	10.083
3	50	0.330	10.330
4	75	0.743	10.743
5	100	1.320	11.320
6	125	2.063	12.063



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

$= 141600\ N/cm^2$

$= 141.6\ kN/cm^2$

04.

Sol: Total weight = 825+1200 + 325 +150 + 100

= 2600 gm

% wt of material ;

$A_1 \rightarrow \dfrac{825}{2600}\times 100 = 31.7\%$

$A_2 \rightarrow \dfrac{1200}{2600}\times 100 = 46.15\%$

$A_3 \rightarrow \dfrac{325}{2600}\times 100 = 12.5\%$

$A_4 \rightarrow \dfrac{150}{2600}\times 100 = 5.7\%$

Bitumen $\rightarrow \dfrac{100}{2600}\times 100 = 3.8\%$

$$G_t = \frac{100}{\left(\frac{w_1}{G_1}+\frac{w_2}{G_2}+\frac{w_3}{G_3}+\frac{w_4}{G_4}+\frac{w_5}{G_5}\right)}$$

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

$= 2.41$

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

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

$= 4.15\%$

(b) $V_b = \dfrac{w_b}{G_b}\times G_m = \dfrac{3.80}{1.05}\times 2.31 = 8.36$

(c) VMA= $V_v + V_b = 4.15\% + 8.36$

$= 12.51\ \%$

$$VFB = \frac{V_b}{VMA}\times 100$$

$$= \frac{8.36}{12.51}\times 100$$

$= 67\ \%$

05. Ans: G_t =2.48, G_m = 2.30

Sol: $G_t = \dfrac{100}{\dfrac{w_1}{G_1}+\dfrac{w_2}{G_2}+\dfrac{w_3}{G_3}}$

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

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 (%)= $\dfrac{P_{2.5}}{P_{st\,2.5}}\times 100$

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

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

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

= 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: 1002)

08. Ans: (a)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-12, 5th Question -pg: 1002)

09. Ans: (c)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-12, 10th Question -pg: 1003)

10. Ans: (a)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-12, 21st Question -pg: 1005)

11. Ans: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-12, 30th Question -pg: 1006)

12. Ans: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-12, 56th Question -pg: 1011)

14. Highway Construction and Pavement Maintenance

32. Ans: (c)

Sol: Refer previous GATE-(Cha-4, 2nd Question - 1 mark - pg: 888)

35. Ans: (c)

Sol: Refer previous GATE-(Cha-4, 6th Question - 1 mark - pg: 888)

36. Ans: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-13, 1st Question -pg: 1021)

38. Ans: (c)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-13, 3rd Question -pg: 1021)

41. Ans: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-13, 4th Question -pg: 1021)

44. Ans: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-13, 8th Question -pg: 1022)

15. 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: $N = \dfrac{365\left[(1+r)^n-1\right]\times A\times D\times F}{r}$

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
		$\Sigma N_i = 59\%$	

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

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

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

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

VDF = 3.74

Given LDF = 0.4

Total Traffic = 1860 cv/day

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

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

N = 25.94 × 10^6 csa = 25.87 msa

05. Ans: 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

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

$= 1.26$

06. Ans: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-13, 2nd Question -pg: 1021)

07. And: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-13, 6th Question -pg: 1021)

08. And: (b)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-13, 11h Question -pg: 1022)

09. And: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-13, 15th Question -pg: 1023)

10. And: (a)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-13, 30th Question -pg: 1026)

Conventional Practice Solutions

01. 01. **Given:**

Mean deflection $\overline{D} = 1.45\text{m}$

Standard deviation $\sigma = 0.107$ mm

Pavement temperature = T = 37°C

Moisture correction factor = K = 1.6

Allowable deflection $D_a = 1$ mm

(i) Characteristic deflection $D_c = \overline{D} = 1.45\text{m}$

Standard deviation $\sigma = 0.107$ mm

(ii) Standard temperature = 35°= as per IRC

Deflection after temperature correction

$D_c = (T - 35) \times 0.0065$

$= 1.557 - (37 - 35) \times 0.0065$

$= 1.544$ mm

Deflection after subgrade correction = K × 1.544

= 1.6 × 1.544 = 2.47 mm

Thickness of granular overlay = 550 $\log_{10} \frac{D_c}{DD_a}$

$= 550 \log_{10} \frac{2.47}{1}$

= 216.02 mm i.e 21.6 cm

02.

Sol: No of Repetitions in an year = 365 × $\sum\left(\frac{\text{Mean weight}}{80}\right)^4 \times \text{No.of axles}$

$$= 365\left[\left(\frac{1.5}{80}\right)^4 \times 14 + \left(\frac{2.5}{80}\right)^4 \times 76 + \left(\frac{3.5}{80}\right)^4 \times 77\right.$$

$$+\left(\frac{4.5}{80}\right)^4 \times 70 + \left(\frac{5.5}{80}\right)^4 \times 28 + \left(\frac{6.5}{80}\right)^4 \times 18$$

$$+\left(\frac{8.5}{80}\right)^4 \times 11 + \left(\frac{9.5}{80}\right)^4 \times 11 + \left(\frac{10.5}{80}\right)^4 \times 11$$

$$+\left(\frac{11.5}{80}\right)^4 \times 12 + \left(\frac{12.5}{80}\right)^4 \times 15 + \left(\frac{13.5}{80}\right)^4 \times 7$$

$$+\left(\frac{14.5}{80}\right)^4 \times 3 + \left(\frac{15.5}{80}\right)^4 \times 1$$

= 365 [0.0344]

= 12.579 axle

03.

Sol:

After correcting for initial concavity loads at 2.5 mm & 5 mm penetration = 55 & 78 kg respectively.

Area of plunger of 5 cm diameter

= 19.6 cm^2

Pressure at 2.5 mm penetration

$= \frac{55}{19.6} \text{kg/cm}^2$

Pressure at 5 mm penetration= $\frac{78}{19.6} \text{kg/cm}^2$

CBR value at 2.5 mm

$$= \frac{\text{Pressure at plunger at 2.5mm penetration for stone}}{\text{Pressure as above for standard stone}}$$

$$= \frac{55}{19.6} \times \frac{100}{70} = 4.0 \text{ percent}$$

$$\text{CBR at 5 mm} = \frac{78 \times 100}{19.6 \times 105} = 3.8 \text{ percent}$$

Adopt CBR = 4%

04.

Sol: Present traffic = 1000 cv/day

Traffic after completion of strengthening

= 1000 (1 + 0.1)^5

= 1611 cv/day

No. of commercial vehicles per day in design lane

= 1611 × 0.75

Cumulative standard axles

= 365 × 1611 × 0.75 × 3 [(1 + 0.1)^{15} – 1]

= 42.03 msa

So we can design for 50 msa traffic data

SDBC	50 mm
DBM	50 mm
Aggregate layer	100 mm
CT Base	190 mm
GSB	250 mm

05.

Sol: Area of steel per metre length of longitudinal joint

$$A_S = \frac{b\,f\,h\,w}{100\,S_S}$$

$$= \frac{3.75 \times 1.5 \times 20 \times 2400}{100 \times 1400}$$

= 1.93 cm^2 per m length

For 15 m length

$$A_{st} = 15\,A_S$$

$$= 28.93 \text{ cm}^2$$

06.

Sol: $A_S = \dfrac{b\,f\,h\,w}{100\,S_S}$

$$= \frac{7 \times 1.3 \times 24 \times 2400}{100 \times 1400}$$

= 3.744 cm^2

Assume 1 cm diameter of bar

No. of tie bar Required $= \dfrac{3.744}{0.785}$

$= 4.77 \approx 5$

Spacing of tie bar $= \dfrac{100}{5} = 20\,\text{cm}$

07.

Sol: $\delta' = \dfrac{2.5}{2}$

= 1.25 cm

$T_2 - T_1 = 54 - 10 = 44^o$ C

$\delta' = L\,\alpha\,\Delta T$

$$L = \frac{\delta'}{\alpha \Delta T}$$

$$L = \frac{1.25}{100 \times 10 \times 10^{-6} \times 44}$$

L = 28.5 m

16. Rigid Pavements

01. Ans: (a)

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

= 35.71 m

(δ' = 50% of gap expansion joint)

Common data for Questions 02 & 03

02. Ans: (a)

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

$$= \frac{0.92 \times 3 \times 10^5 \times 10 \times 10^{-6} \times 16.2}{2}$$

= 22.35 kg/cm^2

03. Ans: (d)

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

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

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

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

$= 8.75$ kg/cm^2

Common data for Questions 04 & 05

04. Ans: (a)

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

$=137.22$ cm^2/m

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

$= 57.23$ cm $\simeq$ 550mm c/c

05. Ans: (b)

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

Common data for Questions 06 & 07

06. Ans: (c)

Sol: $L = \dfrac{2\sigma_c}{\gamma_c f} = \dfrac{2\times0.8\times10^4}{2400\times1.5} = 4.4\,\text{m c/c}$

07. Ans: (c)

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

$= \dfrac{200\times1200\times\dfrac{\pi}{4}\times\left(10\times10^{-1}\right)^2}{3.75\times20\times2400\times1.5}\times$ no. of bars

$= 8.72$ c/c

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

08. Ans: (a)

Sol: $\sigma_f = \dfrac{\gamma_c\,f\,L}{2\times10^4} = \dfrac{2400\times4\times1.2}{2\times10^4}$

$= 0.576\,\text{kg/cm}^2$

09. Ans: (b)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-14, 1st Question -pg: 1032)

10. Ans: (c)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-14, 5th Question -pg: 1032)

11. Ans: (c)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-14, 8th Question -pg: 1033)

12. Ans: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-14, 12th Question -pg: 1033)

13. Ans: (b)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-14, 24th Question -pg: 1035)

17. 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

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

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

Always the time mean speed is more than space mean speed i.e, $V_t > V_s$

03. Ans: 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 kmph

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

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

$= 40.91$ kmph

04. Ans: 4000 veh/hr

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

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

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

Peak hour volume (q)

= 700 + 812 + 1000 + 635

= 3147

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

05.

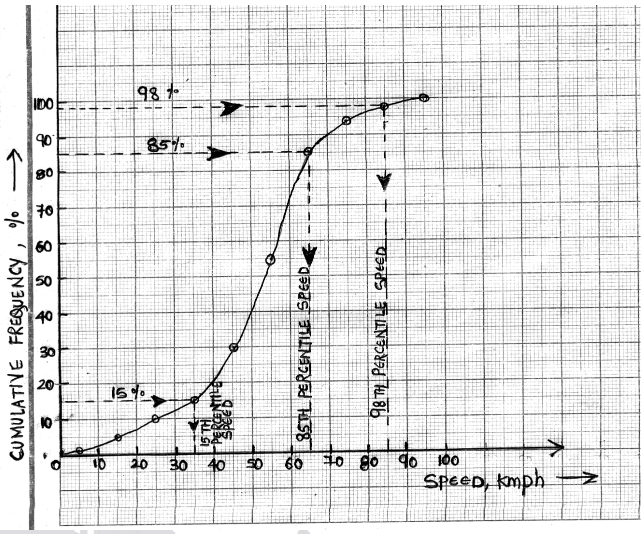
Sol: Total frequency = 100

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

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

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

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



06. Ans: (c)

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

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

$= 86.7$ m

$$S = SSD + L = 86.7 + 5 = 91.7\text{ m}$$

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

$$\simeq 709 \text{ veh / hr / lane}$$

07. Ans: (b)

Sol: $t = 0.7$ Assume

$\text{SSD} = 0.278\,Vt = 7.78$ m

$S = SSD + L = 12.78$ m

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

$\simeq$ 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

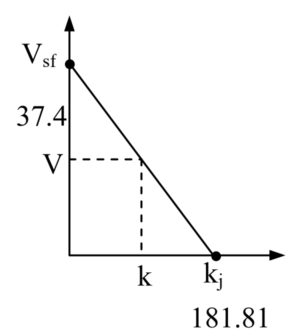
$$k_m = \frac{1000}{S} = \frac{1000}{5.5} = 181.81$$

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

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

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

$$q = v.k$$

$$1000 = \frac{37.4}{181.81} \times (181.81 - k) \times k$$

$$4861.23 = (181.81 - k)k$$

$$4861.23 = 181.81\,k - k^2$$

$$k = 149 \text{ veh/km and } k = 32.6 \text{ veh/km}$$

$$\simeq 33 \text{ veh/km}$$

13. Ans: 35.7 kmph

Sol: $V_{sf} = 50$ kmph

$t_j = 70$ veh/km

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

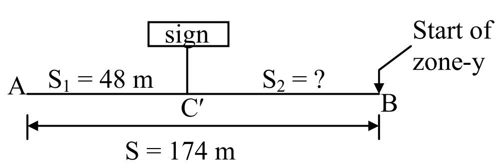
$K = 20$ veh/km

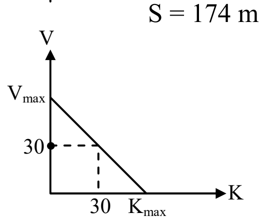
$$\frac{K_j}{V_{sf}} = \frac{K_j - K}{V - 0}$$

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

14. Ans: 1268 veh/hr

Sol:





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

$K_{max} = 130$ veh/km

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

$$= 39 \text{ kmph}$$

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

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

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

$$p = \frac{\text{Crossing traffic}}{\text{Total traffic}} = \frac{1000}{2000} = 0.5$$

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

$$= 3733.33 \text{ PCU/hr}$$

16. Ans: 2064.10 veh/hr

Sol: $w = 6$m ; $p = 0.5$

$L = 20$ m ; $e = 5.5$ m

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

$$Q_p = 2064.10 \text{ veh / hr}$$

17. Ans: 0.8%

Sol: Weaving ratio = $\dfrac{\text{weaving traffic}}{\text{total traffic}}$

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

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

Weaving ratio = 0.80%

18. Ans: (b)

Sol: $\left.\begin{array}{l} y_N = \dfrac{1000}{2500} \\ y_S = \dfrac{700}{2500} \end{array}\right\} y_{NS} = 0.4$

$\left.\begin{array}{l} y_E = \dfrac{900}{3000} \\ y_W = \dfrac{550}{3000} \end{array}\right\} y_{EW} = 0.3$

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

$= 0.4 + 0.3 = 0.7$

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

$S \rightarrow$ Saturation flow

$g_i \rightarrow$ effective green time

$C_o \rightarrow$ Cycle time/Optimum signal cycle length

$\dfrac{g_i}{C_o} \rightarrow$ Green Ratio

$C = 2800 \times 0.55$

= 1540 veh/hr

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

$$= \frac{\dfrac{90}{2}(1 - 0.55)^2}{1 - \dfrac{1000}{2800}} = 14.2 \text{ /veh}$$

21. Ans: (a)

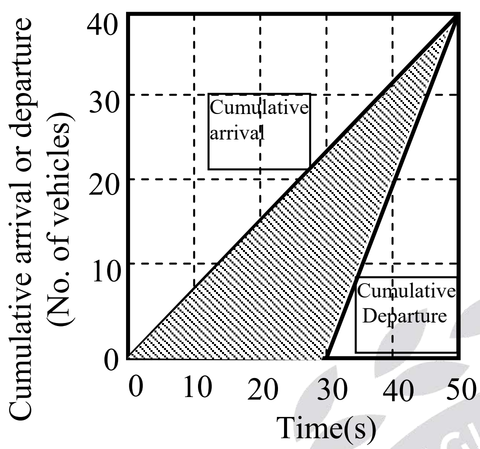
Sol: Average delay at red signal is $= \dfrac{\text{red time}}{2}$

$= \dfrac{30}{2}$

= 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

∴ 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 ($V_b = 0$)

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

Equating (1) & (2)

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

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

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

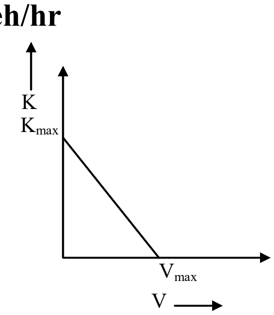
$$\Rightarrow V = \frac{5}{25 \times 0.2}$$

$\Rightarrow$ 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

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

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

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

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:

Sol:

Given:

Speed of the vehicle = 60 kmph

Amber duration = 4 sec

Comfortable deceleration = 3m/sec^2

Car length = 4.0 m

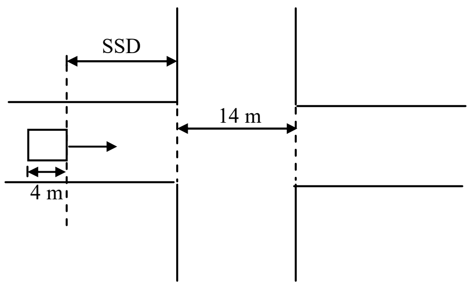
Intersection width = 14

Longitudinal friction factor = 0.35

Perception reaction time = 1.5 sec

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

There are two possibilities



(i) Driver decides to cross intersection:

Total distance to be covered

$= SSD + 14 + 4.0$

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

$$= (16.67\times1.5)+\frac{(16.67)^2}{2\times9.81\times0.35}$$

$= 65.47$ m

Total distance to be covered

$= 65.47 + 14 + 4 = 83.47$ m

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

$$= \frac{83.47}{16.67} = 5.0 \text{ sec} > 4 \text{ sec}$$

(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)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-15, 4th Question -pg: 1040)

30. Ans: (c)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-15, 24th Question -pg: 1044)

Conventional Practice Solutions

01.

Sol: Time mean speed $= \frac{V_1+V_2+V_3+V_4}{4}$

$$= \frac{20+35+40+45}{4}$$

$= 35$ kmph

Space mean speed = $\dfrac{\sum n_i}{\sum \dfrac{n_i}{v_i}}$

$$= \frac{4}{\frac{1}{20}+\frac{1}{35}+\frac{1}{40}+\frac{1}{45}} = 31.8 \text{ kmph}$$

02.

Sol:

Speed range kmph	Mid speed kmph	Frequency f	Frequency %	Commulative Frequency %
Column- 1	2	3	4	5
0 – 10	5	12	1.41	1.41
10 – 20	15	18	2.12	3.53
20 – 30	25	68	8.00	11.53
30 – 40	35	89	10.47	22.00
40 – 50	45	204	24.00	46.00
50 – 60	55	255	30.00	76.00
60 – 70	65	119	14.00	90.00
70 – 80	75	43	5.06	95.06
80 – 90	85	33	3.88	98.94
90 – 100	95	9	1.06	100.00
Total		850	100.00	

(1) Upper speed limit for regulation = 85^{th} percentile speed

= 60 kmph

(2) Lower speed limit for regulation = 15^{th} percentile speed

= 30 kmph

(3) Speed to check design elements – 98^{th} percentile speed

= 84 kmph

03.

Sol: (a) $kj = \dfrac{1000}{L}$

V_{sf} = 60 kmph

Theoretical capacity = $\dfrac{V_{sf}k_j}{4}$

$$= \frac{\frac{1000}{6.1}\times 60}{4}$$

= 2459 veh/hr

(b) Maximum Theoretical capacity

$$= \frac{3600}{\text{Time headway}} = \frac{3600}{5}$$

= 720 veh/hr

04.

Sol: $q = k\,u$

$q = k\,(42.76 - 0.22t)$

for q to be maximum

$\frac{dq}{dk} = 0$

$42.76 - 0.44\,k = 0$

$k = 97.18$ veh/km

$u = 42.76 - 0.22 \times 97.18$

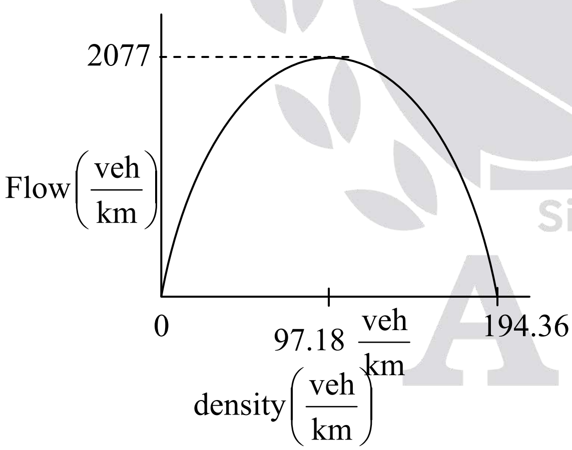
$u = 21.38$ km/hr

$q = ku$

$= 21.38 \times 97.18$

$= 2077$ veh / hr

Comment: q is maximum when $V = \frac{V_{sf}}{2}$ & $q = \frac{qj}{2}$



05.

Sol: $y_a = \frac{q_a}{S_a} = \frac{400}{1250} = 0.32$

$y_b = \frac{q_b}{S_b} = \frac{250}{1000} = 0.25$

$Y = y_a + y_b = 0.57$

$L = 2n + R = 2 \times 2 + 12 = 16$ sec

$C_o = \frac{1.5L + 5}{1 - Y} = \frac{1.5 \times 16 + 5}{1 - 0.57}$

$= 67.5$ sec

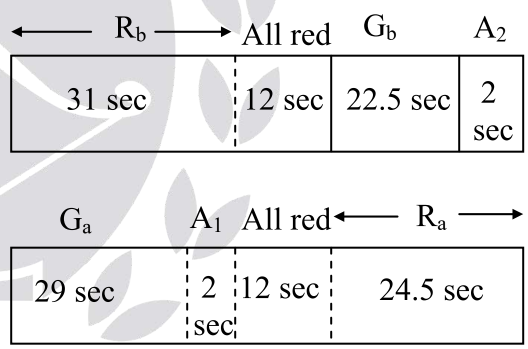
$G_a = \frac{y_a}{Y}(C_o - L) = \frac{0.32}{0.57}(67.5 - 16) = 29\,\text{sec}$

$G_b = \frac{y_b}{Y}(C_o - L) = \frac{0.25}{0.57}(67.5 - 16) = 22.5\,\text{sec}$

All red time for pedestrian crossing = 12 secs

Provide anber time of 2 sec

Total cycle time = 29 + 22.5 + 12 + 4 = 67.5 seconds



06.

Sol:

Saturation flow is 160 PCU/0.3 m with of approach

For road A: Saturation flow

$S_A = \frac{160}{0.3} \times \frac{19}{2} = 5066.673$ PCU/hr

For road B: Saturation flow

$S_B = \frac{160}{0.3} \times \frac{7.5}{2} = 2000$ PCU/hr

Maximum flow road A = q_A = 1360 veh/hr

Maximum flow for road B = q_B = 310 veh/hr

Flow ratio for road

$$A = y_A = \frac{q_A}{S_A} = \frac{1360}{5066.67} = 0.268$$

Flow ratio for road

$$B = y_B = \frac{q_B}{S_B} = \frac{310}{2000} = 0.155$$

Flow ratio for road

$$B = y_B = \frac{q_B}{S_B} = \frac{310}{2000} = 0.155$$

Lost time = 2n + R = 2(2) + 6 + 6 = 16 sec

Cycle time =

$$\frac{1.5L+5}{1-y} = \frac{1.5(16)+5}{1-(0.268+0.155)} = 50.26\,\text{sec}$$

Green time for road A = $\frac{y_a}{4}(C_o - L)$

$$= \frac{0.268}{0.269+0.155}(50.5-16)$$

= 21.86 sec

Say 21.9 sec

Green time for road B = $\frac{y_B}{4}(G - C)$

$$= \frac{0.155}{0.268+0.155}(50.5-16)$$

= 12.64 sec Say 12.6 sec

07.

Sol: Given:

Speed of the vehicle = 50 km/hr

Amber duration = 4.5 sec

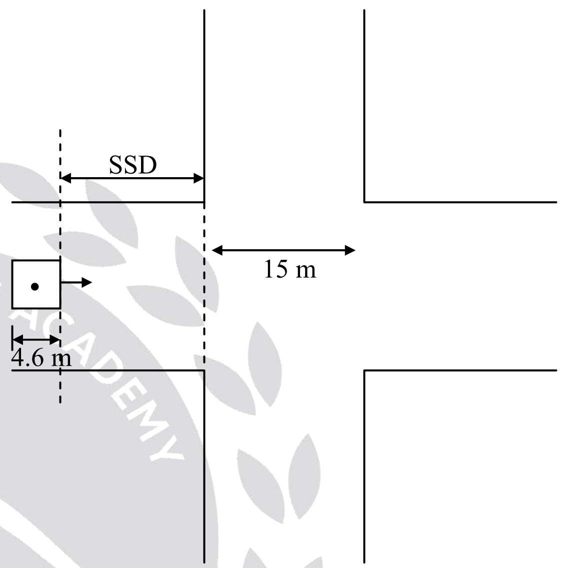
Comfortable deceleration = 3 m/sec^2

Car length = 4.6 m

Intersection width = 15 m

Perception reaction time = 1.5 sec

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



(i) **He decides to cross the intersection:**

Total distance to be covered

= SSD + 15 + 4.6

SSD = Lag distance + Brake distance

$$= v \times t + \frac{v^2}{2\times a} = \left(50\times\frac{5}{18}\right)\times 1.5 + \frac{\left(50\times\frac{5}{18}\right)^2}{2\times 3}$$

Road	Green	Amber	Red	Cycle
A	21.9	6	22.6	50.5
B	12.6	6	31.9	50.5

= 2

0.83 + 32.15 = 52.98 m

Total distance to be covered

= 52.98 + 15 + 4.6 = 72.58 m

Time required = $\dfrac{72.58}{\left(50\times\dfrac{5}{18}\right)}$

= 5.23 sec > 4.5 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

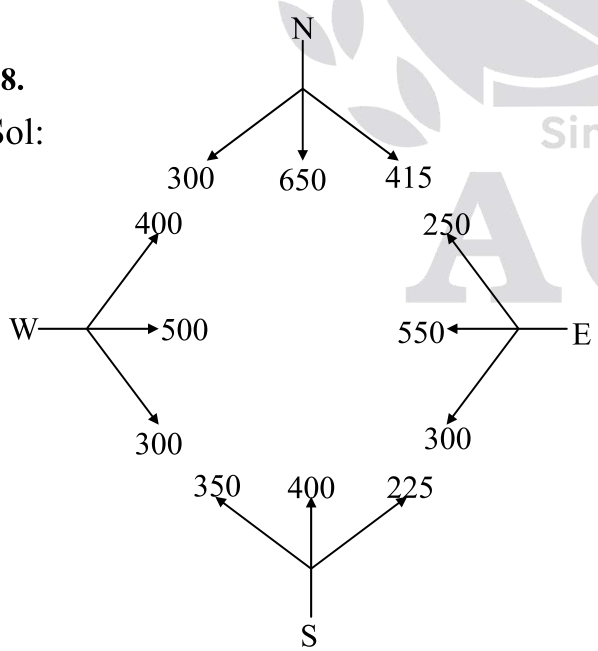
$$=1.5+\frac{\left(50\times\frac{5}{18}-0\right)}{3}=1.5+4.63$$

= 6.13 sec > 4.5 sec

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

08.

Sol:



(i) Since it is urban area, as per IRC, design speed = 30 kmph

(ii) Radius of curve at entry = $\dfrac{V^2}{127f}$

f = 0.47

$\therefore R_{entry}$

$= \dfrac{40^2}{127\times 30} = 26.8\text{m}$ say 27 m

(iii) Radius of curve at exist = (1.5 to 2) R_{entry}

= 2 × 27 = 54 m

(iv) Radius of central traffic island

= 1.33 × R_{entry}

= 1.33 × 27 = 35.91 m say 36 m

(v) Let width of carriageway at entrance e_1

= 8 m

(vi) Width of weaving section

$= \dfrac{e_1+e_2}{2}+3.5$

$w = \dfrac{8+8}{2}+3.5$

= 11.5 m

(vii) Length of weaving section = 4w

= 4 × 11.5 = 46 m

(viii) Proportion of weaving traffic

$= \dfrac{\text{Weaving traffic}}{\text{Total traffic}}$

$$P_{NE} = \frac{300+650+500+225}{300+650+500+225+415+300}$$

= 0.7

$$P_{ES} = \frac{500+600+650+300}{500+600+650+300+300+300}$$

= 0.773

$$P_{SW} = \frac{400+225+550+300}{400+225+550+300+350+250}$$

$$= 0.7108$$

$$P_{WN} = \frac{500+300+400+250}{500+300+400+250+225+400}$$

Maximum proportioning ratio gives minimum capacity

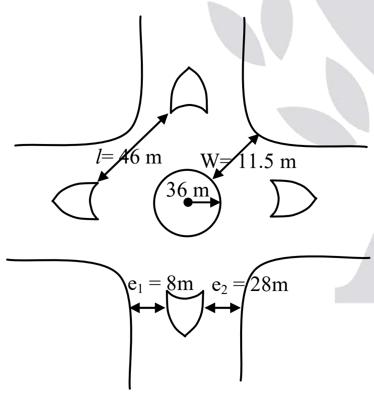
$\therefore$ $P_{min} = P_{wn} = 0.698$

Capacity of the rotary

$$= \frac{280w\left(1+\frac{e}{w}\right)\left(1-\frac{P}{3}\right)}{\left(1+\frac{W}{L}\right)}$$

$$= \frac{280\times 11.5\left(1+\frac{8}{11.5}\right)\left(1-\frac{0.698}{3}\right)}{\left(1+\frac{11.5}{46}\right)}$$

$= 3351.71$ veh/hr



09.

Sol: Correction for elevation

Basic length is increased by 7% per 300 m above M.S.L

Correction for elevation

$$= \frac{7}{100}\times\frac{600}{300}\times 1800$$

$= 252$ m

Length of runway after elevation down

$= 1800 + 252 = 2052$ m

Temperature correction:

Temperature at R.L = 600 m

$$= 15 - 6.5 \times \frac{600}{1000}$$

$= 11.1^{o}$ C

Difference between airport reference and standard atmospheric temperature

$21.6 - 11.1 = 10.5^{o}$ C

Apply correction of 1% per 1^{o} C

Correction for temperature

$$= 2052\times\frac{1}{100}\times 10.5$$

$= 215.46$ m

Corrected runway length $= 2052 + 215.46$

$= 2267.46$ m

Correction for Gradient

20% for 1% effective gradient

$$= \frac{20}{100}\times 2267.46\times 0.6$$

$= 272.1$ m

Actual length of runway $= 272.1 + 2267.46$

$= 2539.55$ m

Check:

Total correction for elevation and temperature

$$= \frac{2267.46 - 1800}{1800} \times 100$$

$= 26\%$

According to 1CAO, this should not be more than 35%.

10.

Sol:

(1) Turning radius:

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

$$= \frac{50^2}{125 \times 0.13}$$

$= 153.85$ m

(2) Horon jeff = n

$$R = \frac{0.388 W^2}{\frac{T}{2} - S}$$

W = Wheel bar of aircraft = 35 m

T = widen of taxiway pavement = 27 M

S = distance between point midway of the main gears and edge of taxiway pavement

$$= 6 + \frac{7.5}{2} = 9.75 \text{ m}$$

$$R = \frac{0.388 \times 35^2}{\frac{27}{2} - 9.75} = 126.75 \text{ m}$$

(3) Absolute minimum turning radius for supersonic aircraft irrespective of any speed = 180 m.

So, adopt turning radius = maximum value of above 3 i.e. 180 m.

11.

Sol: End to end of runway

Chains	Metres	Gradient
0 – 5	0 – 120	+ 1
5 – 15	120 – 360	- 1
15 – 30	360 – 720	+ 0.8
30 – 40	720 – 960	- 0.8

Chainage	Elevation
(m)	(m)
0	100.00
120	101.2
360	98.8
720	101.68
960	99.76

Maximum difference in elevation

= (101.68 – 98.8)

= 2.88 m

Total runway length = 960 m

$$\text{Effective gradient} = \frac{2.88}{960} \times 100$$

= 0.3%

18. Railway Engineering

18.1 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 % = $\dfrac{1}{250} \times 100 = 0.4\%$

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

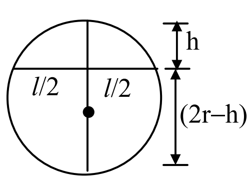
Compensated gradient = $0.4 - 0.12$

$= 0.28\%$

$= \dfrac{0.28}{100} = \dfrac{1}{357}$

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%

$= 0.42\% = \dfrac{1}{238}$

08. Ans: (c)

Sol:

Curve resistance $= 0.04\% \times D°$

$= 0.04 \times 4 = 0.16\%$

Ruling gradient = $\dfrac{1}{150}$

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

Compensated gradient

$= 0.67 - 0.16$

$= 0.51\%$

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

10. Ans: 91.26 kmph

Sol: Given, $D° = 2°$

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

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 × e

L = 7.20 × 12 = 86.4cm

(b) Based on rate of change of cant deficiency

$L = 0.073\ DV_{max}$

L = 0.073 × 7.6 × 85

L = 47.158cm

(c) Based on rate of change of super elevation

$L = 0.073e\ V_{max}$

L = 0.073 × 12 × 85

L = 74.46cm

∴ Take maximum L = 86.4cm

18. 2 TRACTIVE RESISTANCES AND HAULING CAPACITY

01. Ans: (b)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-1, 2nd Question -pg: 1061)

02. Ans: (c)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-1, 3rd Question -pg: 1061)

03. Ans: (c)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-1, 4th Question -pg: 1061)

04. Ans: (b)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-1, 5th Question -pg: 1061)

18. 3 POINTS & CROSSING

01. Ans: (a)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-3, 1st Question -pg: 1070)

02. Ans: (a)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-3, 2nd Question -pg: 1070)

03. Ans: (b)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-3, 3rd Question -pg: 1070)

04. Ans: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-3, 5th Question -pg: 1070)

05. Ans: (c)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-3, 6th Question -pg: 1070)

06. Ans: (b)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-3, 7th Question -pg: 1070)

07. Ans: (b)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-3, 8th Question -pg: 1071)

08. Ans: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-3, 9th Question -pg: 1071)

09. Ans: (b)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-3, 10th Question -pg: 1071)

18.4 TRACK JUNCTION

01. Ans: (a)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-3, 4th Question -pg: 1070)

18.5 PERMANENT WAY

03. Ans: (b)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-4, 3rd Question -pg: 1074)

18. 6 STRESSES IN RAILWAY TRACK

01. Ans: (a)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-4, 5th Question -pg: 1074)

18.8 CREEP OF RAILS

01. Ans: (a)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-5, 10th Question -pg: 1078)

02. Ans: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-5, 11th Question -pg: 1078)

18.9 SLEEPER

01. Ans: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-5, 7th Question -pg: 1077)

02. Ans: (b)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-5, 8th Question -pg: 1078)

03. Ans: (a)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-5, 9th Question -pg: 1078)

18.11 BALLAST

01. Ans: (a)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-4, 6th Question -pg: 1074)

18.12 MATERIAL REQUIRED FOR RAILWAY TRACK

01. Ans: (c)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-4, 2nd Question -pg: 1074)

18.15 STATION AND YARDS

01. Ans: (c)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-6, 3rd Question -pg: 1082)

02. Ans: (b)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-6, 9th Question -pg: 1084)

18.16 EQUIPMENT IN STATION YARD

01. Ans: (b)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-6, 7th Question -pg: 1083)

18.17 SIGNALLING AND CONTROL SYSTEM

01. Ans: (b)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-7, 2nd Question -pg: 1087)

02. Ans: (a)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-7, 3rd Question -pg: 1087)

03. Ans: (c)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-7, 4th Question -pg: 1087)

04. Ans: (c)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-7, 5th Question -pg: 1087)

05. Ans: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-7, 6th Question -pg: 1087)

06. Ans: (b)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-7, 7th Question -pg: 1088)

18.19 TRACK MODERNISATION

01. Ans: (b)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-6, 2nd Question -pg: 1082)

02. Ans: (c)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-6, 6th Question -pg: 1083)

03. Ans: (b)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-6, 5th Question -pg: 1083)

04. Ans: (c)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-6, 8th Question -pg: 1083)

05. Ans: (b)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (Cha-6, 10th Question -pg: 1084)

Conventional Practice Solutions

01.

Sol: $e_{eq} = \frac{1.35V^2}{R}$

$= \frac{1.35 \times 80^2}{1719/3}$

$= 15.08$ cm

(i) Actual cont required

$e_{th} = e_{eq} + C.D$

$= 15.08 + 7.5$

$e_{th} = 22.58$ cm

(ii) Permissible speed $V = \sqrt{\frac{eR}{1.35}}$

$= \sqrt{\frac{22.58 \times (1719/3)}{1.35}}$

$= 97.9$ kmph --- (1)

According to Railway Board formula

$V = 4.4\sqrt{R - 70}$

$= 4.4\sqrt{\frac{1719}{3} - 70}$

$= 98.68$ kmph ----- (2)

Hence $V_{max} = 97.9$ kmph [lower of (1) & (2)]

(iii) Length of transition curve

(a) $L = 7.2$ e

$= 7.2 \times 22.58 = 162.586$ m

(b) $L = 0.073\ D\ V_{max}$

$= 0.073 \times 7.5 \times 97.9$

$= 53.6$ m

(c) $L = 0.073\, e\, V_{max}$

$= 0.073 \times 22.58 \times 97.9$

$= 161.37$ m

Hence provide L = 162.576 ≈ 165 m

(iv) Offsets at every 10 m interval are calculated from cubic parabola equation as follows

$$Y = \frac{x^3}{6RL} = \frac{x^3 \times 100}{6 \times 573 \times 165}\text{cm} = \frac{x^3}{5673.0}\text{cm}$$

x(m)	y (cm)
10	0.176
20	1.408
30	4.752
40	11.264
50	22
60	38.016
70	60.37
80	90.112
90	128.3
100	176
110	234.26
120	304.13
130	386.67
140	428.94
150	594
160	720.87
165	790.61

02.

Sol: (i) S.E of Branch track $= \dfrac{0.8V^2}{R}$

$$= \frac{0.8 \times 30^2}{(1719/6)}$$

$= 2.51$ cm

-ve super elevation = (2.51 – 5) = - 2.49 cm

Maximum S.E on main line = 2.49 cm

Theoretical S.E = 2.49 + 5 = 7.49 cm

$$7.49 = \frac{V^2}{(1719/3)} \times 0.8$$

V = 73.24 kmph ------ (1)

Maximum permissible speed

$$V = 4.4\sqrt{R - 70}$$

$$= 4.4\sqrt{\frac{1719}{3} - 70}$$

= 98.68 kmph ----- (2)

So adopt lower value of (1) & (2)

V = 73.24 kmph

(ii) $e_{th} = \dfrac{0.8V^2}{R}$

$$= \frac{0.8 \times 70^2}{(1719/3)} = 6.84 \text{ cm}$$

$e_{th} = e_{act} + CD$

$6.84 = e_{act} + 5$

$e_{act} = 1.84$ cm

For branch track:

$e_{act} = -1.84$ cm

$e_{th} = e_{act} + CD$

$= -1.84 + 5 = 3.16$ cm

$$e_{th} = \frac{0.8V^2}{R}$$

$$3.16 = \frac{0.8 \times V^2}{(1719/6)}$$

V = 33.64 kmph

Check:

$$V_{max} = 4.4\sqrt{R-70} = 4.4\sqrt{\frac{1719}{6}-70}$$

= 64.74 kmph

Hence V = 33.64 kmph is ok

04.

Sol: Deviation angle N = 0.03 – (0.04) = 0.07

Length of valley curve

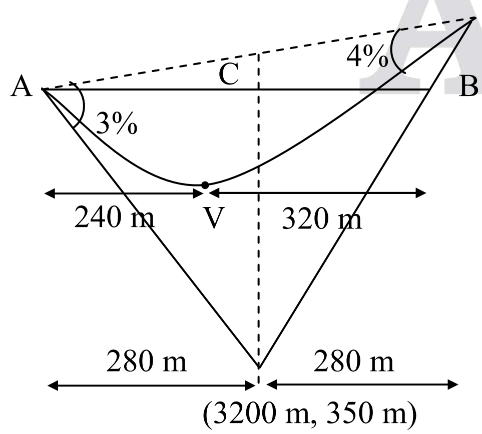
$$= \frac{\text{Deviation angle}}{\text{Rate of change of gradient}}$$

$$= \frac{7}{0.25} = 28\,\text{chains}$$

Assume chain length = 20 m

Length of valley curve = 560 m

Intersection of gradients is



At mid point of curve (C)

So changing of A

$$= 3200 - \frac{560}{2} = 2920\,\text{m}$$

Change of B

$$= 3200 + \frac{560}{2} = 3480\,\text{m}$$

Chainage of valley point

$$= \frac{n_2}{(n_1+n_2)}L = \frac{4}{7} \times 560 = 320\,\text{m from B} =$$

240 m from A

RL of C = RL of A – N_1 x + $\frac{Nx^2}{2L}$

350 = R.L of A – 0.03 × 280 + $\frac{0.07 \times 280^2}{2 \times 560}$

350 = R.L of A – 8.4 + 4.9

R.L of A = 353.5 m

RL of B = RL of A – N_1 x + $\frac{Nx^2}{2L}$

= 353.5 – 0.03 × 560 + $\frac{0.07 \times 560^2}{2 \times 560}$

RL of B = 356.6 m

R.L of valley point = RL of A – n_1 x + $\frac{Nx^2}{2L}$

= 353.5 – 0.03 × 240 + $\frac{0.07 \times 240^2}{2 \times 560}$

= 353.5 – 7.2 + 3.6

= 349.9 m

05.

Sol: Having capacity of loco motive

$$= \frac{1}{6} \times 3 \times 21$$

$$= 10.5 \text{ tonne}$$

(a) On a straight track, train resistance

= Resistance due to friction wave action + resistance due to speed

$10 = 0.0025\ W + 0.0000015\ WV^2$

$W = 826.44$ tonne

(b) Total Train resistance

$= 0.0025\ W + 0.0000015V^2W + W \times \frac{1}{\text{rate of grade}}$

$10.5 = 0.0025 \times 826.44 + 0.0000015\ V^2 \times 826.44 + \left(826.44 \times \frac{1}{200}\right)$

$V = 58.9$ kmph

(c) Total Train Resistance

$10.5 = 0.0025\ W + 0.0000015\ WV^2 + 0.0004 \times 3 \times W$

$W = 826.44$ tonne

$10.5 = 2.0661 + 0.992 + (1.24 \times 10^{-3})\ V^2$

$V = 77.47$ kmph

(d) Total train Resistance

$= 0.0025\ W + 0.0000015\ WV^2 + 0.0004 \times 3 \times W + W \times \frac{1}{\text{rate of grade}}$

$10.5 = 2.0661 + (1.24 \times 10^{-3})\ V^2 + 0.992 + 4.1322$

$V = 51.66$ kmph

06.

Sol: **(a)**

Curve is starting from toe of switch and end at theoretical nose of crossing

$\therefore$ Using Coles method:

Crossing number N = 12

Curve lead = CL = 2GN

$= 2 \times 1.676 \times 12 = 40.224$ m

Radius of outer curve $R_o = 1.5G + 2GN^2$

$= (1.5 \times 1.676) + (2 \times 1.676 \times 12^2)$

$= 485.202$ m

Radius of centre line $= R_o - \frac{G}{2} = 484.364\text{ m}$

Switch lead $= \sqrt{2R_o d} = \sqrt{2 \times 485.202 \times 0.12}$

$= 10.79$ m

Lead = LL – SL

$= 40.224 - 10.79 = 0$

(b) Curve is starting from heel of switch and ends at TNC

Crossing number $N = 16 = \cot\alpha$

$A = 3^o\ 34'\ 34.8''$

Angle of switch $P = 1^o\ 30'00''$

Radius of outer curve $= \frac{G - d}{\cos\beta - \cos\alpha}$

$= \frac{1.676 - 0.12}{\cos(1^o 30'00'') - \cos(3^o 34' 34.8'')}$

$= 969.62$ m

Radius of centre line $= R_o - \frac{G}{2} = 968.78\text{m}$

Lead $= (G - d) \cot \frac{(\alpha + \beta)}{2}$

$$= (1.676 - 0.12)\cot\frac{(1°30' + 3°34'\ 34.8'')}{2}$$

= 35.1 m

Switch lead = $\sqrt{2R_od} = \sqrt{2 \times 969.62 \times 0.12}$

= 15.25 m

Curve lead = L + SL

= 35.1 + 15.25 = 50.35 m

(c) Straight portion before TNC = x = 1.3 m

Curve is provided between heel of switch and starting point of straight portion

N = 12 ; $\beta = 1^o\ 30'$

$\Rightarrow \cot\alpha = 12$

$\Rightarrow \alpha = 4^o\ 45'\ 49.11''$

Lead = x cosα + (G – d – xsinα)

$$\left(\cot\left(\frac{\alpha+\beta}{2}\right)\right)$$

= 1.3 cos ($4^o\ 45'\ 49.11''$) + [(1.676 – 0.12 – 1.3sin ($4^o\ 45'\ 49.11''$) cot

$$\left(\frac{1°30' + 4°45'\ 49.11''}{2}\right)$$

= 1.2955 + (1.448V 18.276)

= 27.76 m

Radius of outer curve = $\dfrac{(G - d - x\sin\alpha)}{\cos\beta - \cos\alpha}$

$$R_o = \frac{1.676 - 0.12 - 1.3\text{sm}(4°45'49.11'')}{\cos(1°30''0'') - \cos(4°45'\ 49.11'')}$$

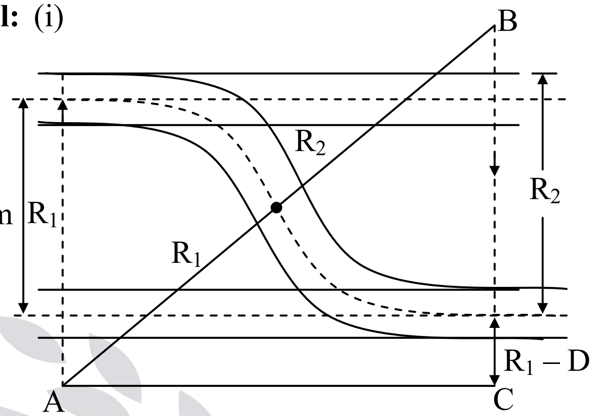
= 465.36 m

Radius of centre line = $R_o - \dfrac{G}{2}$

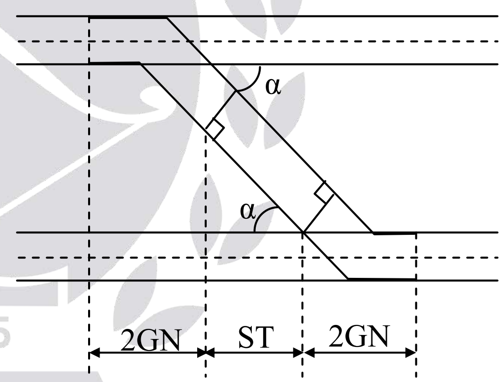
$$= 465.36 - \frac{1.676}{2} = 464.522 \text{ m}$$

07.

Sol: (i)



(ii) Since the intermediate portion is straight the crossing angle with be same. Let the crossing number = 12



Length of cross over = 2G +horizontal projection of straight portion + 2GN

= 4GN + ST

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

= (4 × 1.676 × 12) + (12 – 1.676) × 12 – 1.676 $\sqrt{1+12^2}$

= 184.154 m

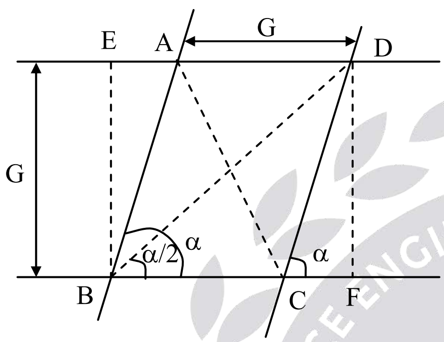
10.

Sol: Let, Angle of crossing = α

Number of crossing N = 4

G = 1.676m for B.G tack

Diamond crossing



From ΔCDF,

$$\sin\alpha = \frac{FD}{CD}$$

Where, FD = G

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

CD = G. cosec α

From figure,

AB = BC = CD = DA = G. cosecα

AB = BC = CD = DA = 1.676 cosecα

We know that, N = cotα

4 = cotα

$\alpha = 14^{\circ}2'10.48''$

(i) AB = BC = CD = DA

$= 1.676.\text{cosec}(14^{\circ}2'10.48'')$

= 6.91 m

(ii) AE = CF = G.cotα = 1.676×4

= 6.704 m

(iii) $AC = 2\ AB \sin\dfrac{\alpha}{2}$

$$= 2 \times 6.91 \sin\left(\frac{14^{\circ}2'10.48''}{2}\right)$$

= 1.688 m

(iv) $BD = G.\text{cosec}\dfrac{\alpha}{2}$

$$= 1.676 \times \text{cosec}\left(\frac{14^{\circ}2'10.48''}{2}\right)$$

BD = 13.72 m

19. Airport Engineering

19.2 RUNWAY

01. Ans: (a)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (23rd Question -pg: 1096)

02. Ans: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (2nd Question -pg: 1093)

03. Ans: (a)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (19th Question -pg: 1096)

04. Ans: (c)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (30th Question -pg: 1098)

05. Ans: (a)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (6th Question -pg: 1093)

19.3 GEOMETRIC DESIGN OF RUNWAY

01. 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

02. 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

03. 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

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

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

ART = 35.57°

Temperature gradient 1000 − 6.5

486 − x

x = 3.159°

Temperature @ airport @ 486 m elevation

= 15 − 3.159 = 11.841°

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 m

Correction for effective gradient

20% $\uparrow \rightarrow$ 1% effective gradient

$x \rightarrow 0.75\%$

$x = 15\%$

Total runway length = 1.15×3388.89

$= 3897.22$ m

$\simeq 4000$ m = 4 km

04. 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

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

05. Ans: (d)

Sol: Given $T_m = 40^oC$

$T_a = 25^oC$

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

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

$= 30^oC$

06. 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 %

$280 \rightarrow x$

$x = 6.53\%$

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

$= 1747.15$ m

Correction for temperature (ICAO)

ART = 33.5°C m

Temperature gradient

1000 m $\rightarrow$ 6.5°

280 m $\rightarrow$ x

x = 1.82°

Temp @ airport @ 280 m elevation

$= 15 - 1.82$

$= 13.18°$

1% increase in length for 1° above standard temperature = $33.5^o - 13.18^o$

$= 20.32^o$

$1^o \uparrow \rightarrow 1\% \uparrow$

$20.32^o \uparrow \rightarrow x$

$x = 20.32\%$

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

$= 2102.17$ m

07. Ans: 0.36 %

Sol:

Chainage	Gradient	Elevation
0	–	280 m
300	+1%	$(280 + 0.01\times300) = 283$
900	–0.5%	$283 - \frac{0.5}{100}\times 600 = 280$
1500	+0.5	$280 + \frac{0.5}{100}\times 690 = 283$
1800	+1	$283 + 0.01\times300 = 286$
2100	–0.5	$286 - \frac{0.5}{100}\times300 = 284.5$
2700	0.4	$284.5 - \frac{0.4}{100}\times 600 = 282.1$
3000	–0.1	$282.1 - \frac{0.1}{100}\times 300 = 281.8$

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

$20\% \rightarrow 1\%$

$x \rightarrow 0.36\%$

$x = 7.2\%\uparrow$

Total length of runway = 1.072×2102.17

$= 2253.5$ m

08. Ans: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (3rd Question -pg: 1093)

09. Ans: (a)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (16th Question -pg: 1095)

10. Ans: (a)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (20th Question -pg: 1096)

11. Ans: (c)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (25th Question -pg: 1097)

12. Ans: (a)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (26th Question -pg: 1097)

13. Ans: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (28th Question -pg: 1097)

14. Ans: (b)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (29th Question -pg: 1098)

15. Ans: (b)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (33rd Question -pg: 1098)

16. Ans: (b)

Sol:

Speed of airplane = 800 km/hr = 222.22 m/sec

Air temperature = 0^oC

Mach number = $\dfrac{\text{Speed of airplane}}{\text{Speed of sound}}$

Speed of round at 0^oC = 331.5 m/sec

as $V \approx 20.05\sqrt{T}$ (T in Kelvin)

$= 20.05\sqrt{273} = 331.28$ m/sec

$\therefore$ Moch number = $\dfrac{222.22}{331.25} = 0.67$

Conventional Practice Solutions

01.

Sol: Given

Basic length of runway = 2000 meters

Elevation of airport site (RL) = 280 meters

Monthly mean of average daily temperature for the hottest month of the year = 35°C

Monthly mean maximum daily temperature for the same month=42°C

Effective gradient = 0.12 %

Correction for Elevation:

(Recommendation of ICAO),

The basic length is to be increased at the rate of 7% per 300 m elevation above mean sea-level.

Therefore,

$$\text{Correction} = \frac{7}{100}\times\frac{\text{Elevation}}{300}\times\text{Basic length}$$

$$= \frac{7}{100}\times\frac{280}{300}\times 2000$$

= 130.67 m

Corrected length, $L' = L + 130.67$

$= 2000 + 130.67$

$= 2130.67$ m

Correction for temperature:

Airport reference temperature,

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

Where

T_1 = mean of average daily temperature

= 35°C

T_2 = Mean of maximum daily temperature

= 42°C

$$T_R = 35 + \frac{42-35}{3}$$

T_R = 37.33 °C

We know that,

Standard atmospheric temperature at mean sea level = 15° C

Taking the temperature gradient as equal to 6.5°C per 1000 m rise in Elevation, the standard temperature at the airport site will be,

Temperature at given elevation

$$= 15 - \left[6.5\times\frac{280}{1000}\right] = 13.18°C$$

Rise in temperature from standard temperature

$= T_R - T_S$

$= 37 - 13.18$

$= 23.82°$ C

ICAO recommends,

Correction for temperature shall be 1% for every 1°C rise in temperature.

Correction = $\frac{1}{100} \times$ (rise in temperature) × L′

$$= \frac{1}{100} \times 23.82 \times 2130.67 = 507.52\,\text{m}$$

Corrected length, L″ = 2130.67 + 507.52

L″ = 2638.19 m

Check:

As per ICAO, total correction for sum of elevation and temperature shall not exceed 35% of basic runway.

Length total correction for elevation and temperature.

= 130.67 + 507.52

= 638.19 m

Total correction in percentage

$$= \frac{638.19}{2000} \times 100$$

= 31.9 % < 35 %

Hence Accepted.

Correction for gradient:

(Recommendation of FAA),

Runway length shall be further increased at the rate of 20 % for energy 1% of effective gradient after being corrected for elevation and temperature.

Correction for gradient

$$= \frac{20}{100} \times 0.12 \times 2638.19$$

= 63.32 m

Final runway length = L″ + 63.32

= 2638.19 + 63.32

= 2701.51 m

19.4 TAXIWAY DESIGN

01. 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

∴ Turning radius = Maximum of three conditions

= 393.85 m

R ≈ 400 m

02. Ans: (b)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (12th Question -pg: 1094)

Conventional Practice Solutions

01.

Sol: **Given:**

Turning speed, V = 60 kmph

Wheel base, W = 35 m

Tread of main landing gear, T′ = 4 m

Co-efficient of friction, f = 0.13

Width of taxiway ,T = 22.5 m

The following three values of R shall be worked out, and maximum of three will be final radius of taxiway.

(i) $R = \frac{V^2}{125f} = \frac{60^2}{125 \times (0.13)} = 221.54\text{m}$

(ii) Horonjeff's equation

$$R = \frac{0.388W^2}{\frac{T}{2} - S}$$

Where S is distance between point midway of main gears and the edge of taxiway pavement.

$S = \text{edge distance} + \frac{T'}{2}$

(Assume edge distance as 6 m)

$S = 6 + \frac{4}{2} = 8\,\text{m}$ ….. (1)

Substituting equation (1) in Horonjeff's equation

$$R = \frac{0.388 \times (35)^2}{0.5(22.5) - 8} = 146.25 \text{ m}$$

(iii) The absolute minimum turning radius for supersonic aircraft irrespective of any speed = 180 m.

The maximum value among the above three is 221.54 m. Hence the radius is approximately 221.54 m.

19.5 PLANNING AND DESIGN OF TERMINAL AREA & VISUAL AIDS

01. Ans: (c)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (1st Question -pg: 1093)

02. Ans: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (4th Question -pg: 1093)

03. Ans: (a)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (5th Question -pg: 1093)

04. Ans: (a)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (8th Question -pg: 1094)

05. Ans: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (11th Question -pg: 1094)

06. Ans: (a)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (13^{th} Question -pg: 1095)

07. Ans: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (14^{th} Question -pg: 1095)

08. Ans: (c)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (15^{th} Question -pg: 1095)

09. Ans: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (17^{th} Question -pg: 1095)

10. Ans: (a)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (21^{st} Question -pg: 1096)

11. Ans: (c)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (22^{nd} Question -pg: 1096)

12. Ans: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (27^{th} Question -pg: 1097)

13. Ans: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (31^{st} Question -pg: 1098)

14. Ans: (b)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (32^{nd} Question -pg: 1098)

15. Ans: (a)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (34^{th} Question -pg: 1099)

16. Ans: (b)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (35^{th} Question -pg: 1099)

17. Ans: (c)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (36^{th} Question -pg: 1099)

19. Ans: (a)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (42^{nd} Question -pg: 1099)

20. Ans: (b)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (39^{th} Question -pg: 1099)

20. Harbour Engineering

01. Ans: (c)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (2^{nd} Question -pg: 1105)

02. Ans: (a)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (4th Question -pg: 1105)

03. Ans: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (5th Question -pg: 1106)

04. Ans: (b)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (7th Question -pg: 1106)

05. Ans: (c)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (8th Question -pg: 1106)

06. Ans: (a)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (9th Question -pg: 1106)

07. Ans: (c)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (10th Question -pg: 1106)

08. Ans: (a)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (8th Question -pg: 1106)

09. Ans: (b)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (12th Question -pg: 1107)

10. Ans: (c)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (13th Question -pg: 1107)

11. Ans: (c)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (14th Question -pg: 1107)

12. Ans: (b)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (15th Question -pg: 1107)

13. Ans: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (16th Question -pg: 1107)

14. Ans: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (17th Question -pg: 1108)

15. Ans: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (18th Question -pg: 1108)

16. Ans: (a)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (19th Question -pg: 1108)

17. Ans: (b)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (20th Question -pg: 1108)

18. Ans: (a)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (21st Question -pg: 1108)

19. Ans: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (22nd Question -pg: 1108)

20. Ans: (a)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (23rd Question -pg: 1108)

21. Ans: (b)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (25th Question -pg: 1109)

22. Ans: (a)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (26th Question -pg: 1109)

23. Ans: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (27th Question -pg: 1109)

24. Ans: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (28th Question -pg: 1109)

25. Ans: (a)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (29th Question -pg: 1110)

26. Ans: (c)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (30th Question -pg: 1110)

29. Ans: (c)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (31st Question -pg: 1110)

31. Ans: (a)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (33rd Question -pg: 1110)

32. Ans: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (34th Question -pg: 1110)

21. Tunnel Engineering

01. Ans: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (4th Question -pg: 1115)

02. Ans: (b)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (5th Question -pg: 1115)

03. Ans: (a)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (6th Question -pg: 1116)

04. Ans: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (7^{th} Question -pg: 1116)

05. Ans: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (8^{th} Question -pg: 1116)

06. Ans: (c)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (9^{th} Question -pg: 1116)

07. Ans: (b)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (10^{th} Question -pg: 1116)

08. Ans: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (11^{th} Question -pg: 1117)

09. Ans: (b)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (12^{th} Question -pg: 1117)

10. Ans: (b)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (13^{th} Question -pg: 1117)

11. Ans: (c)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (15^{th} Question -pg: 1118)

12. Ans: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (16^{th} Question -pg: 1118)

14. Ans: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (17^{th} Question -pg: 1118)

15. Ans: (c)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (18^{th} Question -pg: 1118)

16. Ans: (d)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (19^{th} Question -pg: 1118)

17. Ans: (c)

Sol: Refer previous ESE-Obj-(Vol-2) solutions Book (20^{th} Question -pg: 1118)