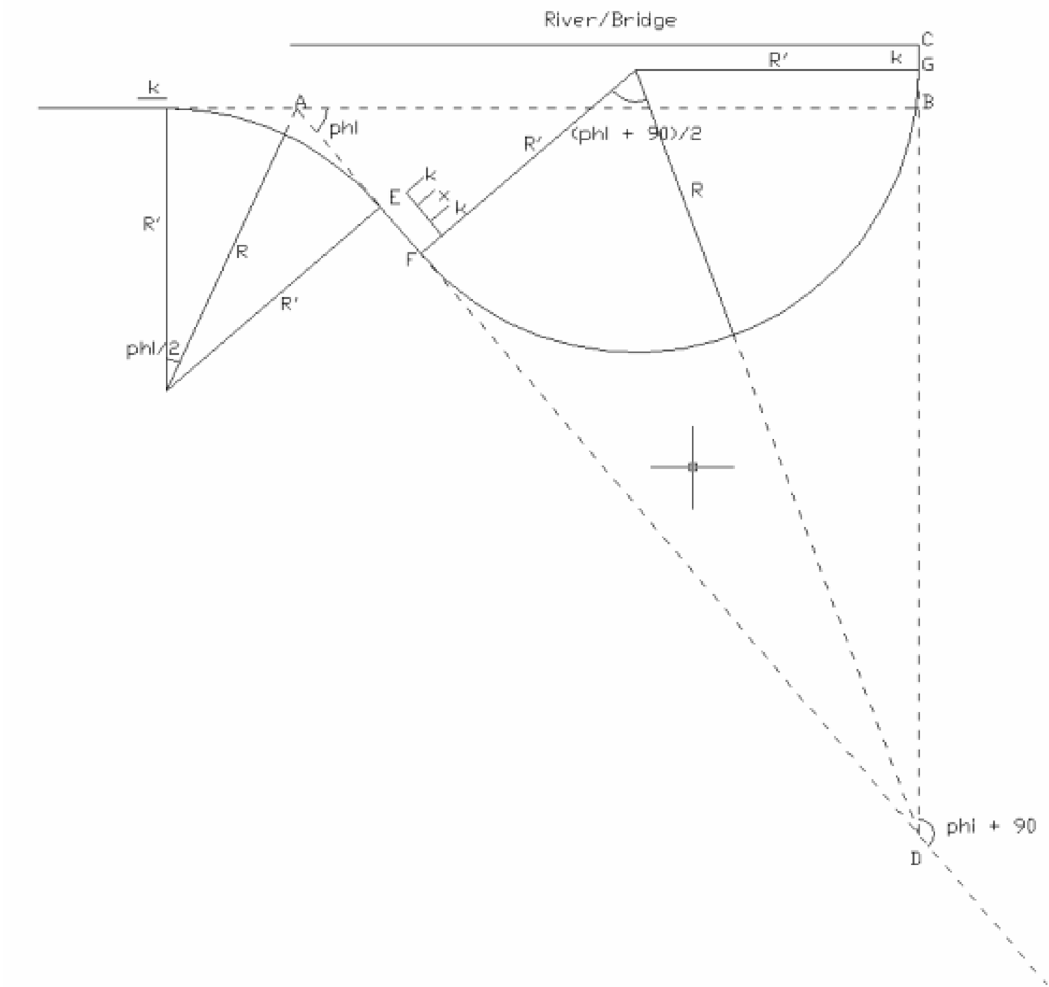
<u>Question 1</u>
Horizontal Alignment

Min radius for safe cornering:
$R = V^2 / [g*(f_s + e)]$
V = 100 km/hr = 27.77 m/s, use e = 0.06 → $f_s = 0.12$
$R = 27.77^2 / [9.81 * (0.12 + 0.06)]$
= 436.9 m → use R = 450 m



BD = DG – 100
= R tan ((90+ φ)/2) – 100
AD = $T_1 + T_2$
= R tan (φ/2) + R tan ((90+ φ)/2)

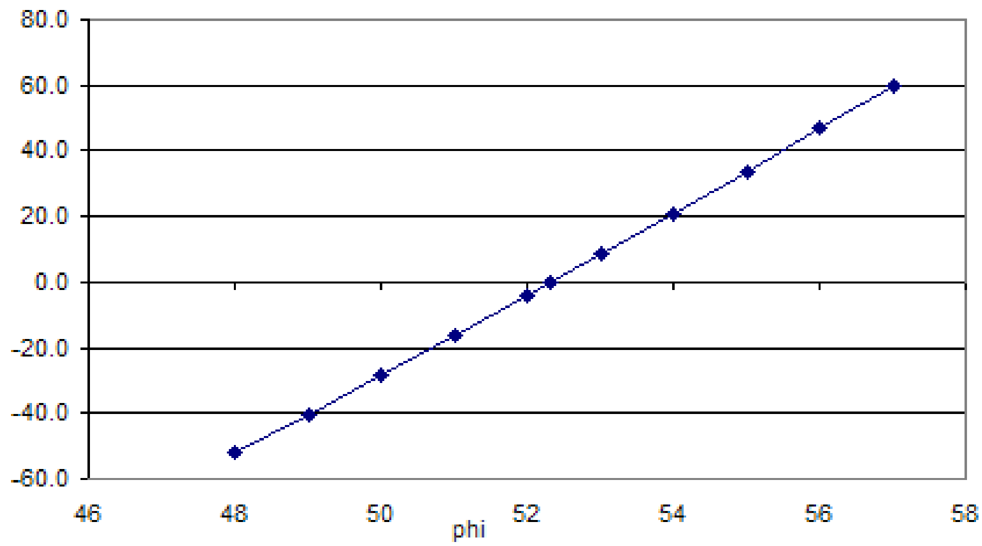
Sin φ = BD / AD
= [R. tan ((90+ φ)/2) – 100] / [R tan (φ/2) + tan ((90+ φ)/2)]

or R. sin φ (tan (φ/2) + tan ((90+ φ)/2) - R. tan ((90+ φ)/2) + 100 = 0 Eq. (A)

Solving the equation we get

$\varphi = 52.33$

Angle	Eq. A
48	-52.22
49	-40.45
50	-28.51
51	-16.39
52	-4.10
52.33	0.00
53	8.37
54	20.99
55	33.78
56	46.73
57	59.82



Vertical Alignment

$d = V_o * t_{pr} + V_o^2 / [2 * g * (f - G)]$ assume f = 0.3, G = 0.02

$= 27.77 * 2.5 + 27.77^2 / [2 * 9.81 * (0.3 - 0.02)]$

$= 209.88$ m ~ 210 m

Crest curve

Assume: $H_1 = 1.07$ m

$H_2 = 0.15$ m

$A = abs(G_2 - G_1) = 2$

$L_m = KA$; $K = SSD^2 / 658$

$= A * SSD^2 / 658$

$= 2 * 210^2 / 658$

$= 134.04$ m

Sag curve

Assume: H = 0.6 m

$\beta = 1^o$

$L_m = KA$; $K = SSD^2 / (120 + 3.5 * SSD)$

$= A * SSD^2 / (120 + 3.5 * SSD)$

$= 2 * 210^2 / (120 + 3.5 * 210)$

$= 103.1$ m

Question 2

5.1)
$u = u_f [1 – (k / k_j)^{3.5}]$
Capacity (q) = 3800 veh/h
Jam density (k_j) = 225 veh/mi = 140 veh/km (1.6 km = 1 mi)

$q = uk$
$= u_f [k – k (k/k_j)^{3.5}]$
$= u_f [k – k^{4.5} / k_j^{3.5}]$
$dq / dk = u_f [1 – 4.5 (k / k_j)^{3.5}] = 0$
$4.5 k^{3.5} = k_j^{3.5}$
$k_m = (1 / 4.5)^{1/3.5} k_j$

$u_m = u_f [1-(k_m / k_j)^{3.5}]$
$= u_f [1 – (1 / 4.5)]$

$q_m = u_m k_m$
$= 0.777 u_f (1 / 4.5)^{1/3.5} k_j$
$3800 = 0.777 u_f (0.6506) (140)$
$\underline{u_f = 53.69 \text{ km/h} = 33.55 \text{ mi/h}}$

$u_m = u_f [1 – (1 / 4.5)]$
$= \underline{41.71 \text{ km/h} = 26.06 \text{ mi/h}}$

5.13)
$t_0 = 7:45am$
$\lambda_1 = 6veh/\min \ (7:45am \le t \le 8:15am)$
$\lambda_2 = 2veh/\min \ (t \ge 8:15am)$
$\mu = 6veh/\min \ (t \ge 8:00am)$

Assume queue dissipation at time t, so
$\lambda_1(30) + \lambda_2(t-30) = \mu(t-15)$
→ t=52.5min @8:37:30am

Total delay: the area between arrival and departure curves
=(15min)[(6)(30)]+1/2(15min)[(6)(52.5-15)-(6)(30)]=3037.5veh.min

Longest queue length: @8:15am
= (6)(30-15)=90vehicles

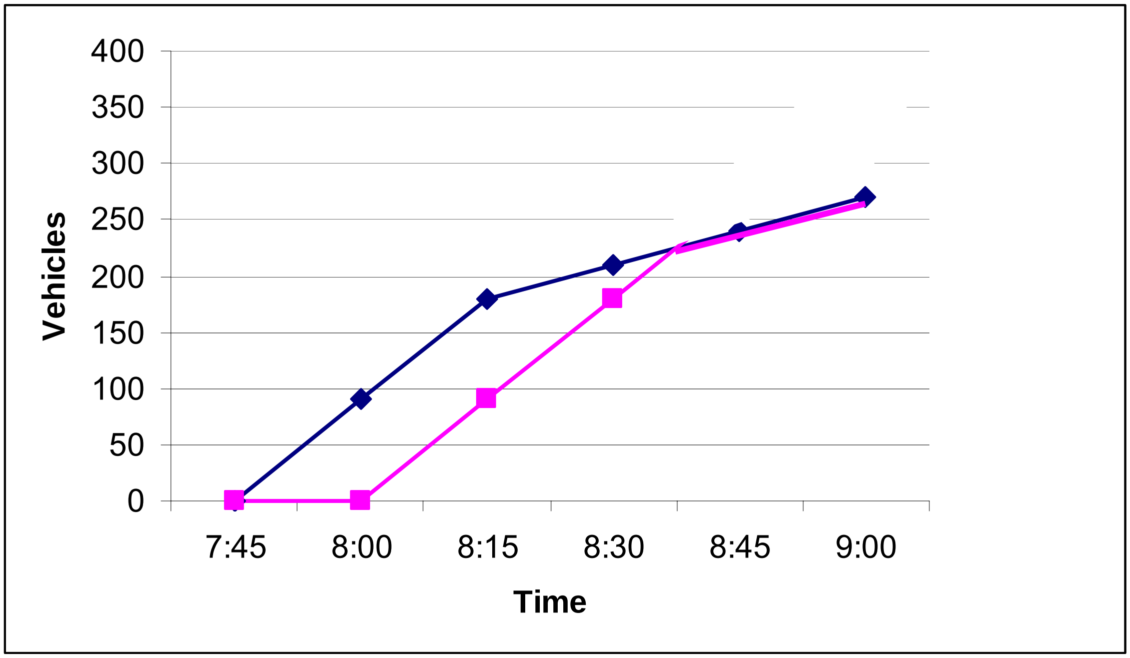
Longest queue delay: =8:30am-8:15am = 15min

For LIFO:

Longest vehicle delay =8:37:30am-7:45am =52.5min

For FIFO:

Longest vehicle delay =8:00am-7:45am =15min



5.31) D/D/1

length of queue at t is $Q(t) = \int_0^t (3.3 - 0.1t)dt - \mu t$

Q(t) = 3.3 t – 0.05 t^2 – μt for maximum $\frac{dQ(t)}{dt} = 0$

$\frac{dQ(t)}{dt} =$ 3.3 – 0.1 t – μ = 0 $\rightarrow t = \frac{3.3 - \mu}{0.1}$

substituting for t

$$Q(t) = \frac{3.3(3.3 - \mu)}{0.1} - 0.5(\frac{3.3(3.3 - \mu)}{0.1})^2 - \mu(\frac{3.3(3.3 - \mu)}{0.1})$$

→ μ = 2.406 veh/min

5.32)
λ = 1.5 veh/min
μ = 2 veh/min
N = 1
$\rho = \lambda / \mu = 1.5 / 2 = 0.75$

$$P_0 = 1/(\sum_{n_c=0}^{N-1} \frac{\rho^{n_c}}{n_c!} + \frac{\rho^N}{N!(1-\rho/N)}) \quad = 1 / [0.75^0 /0!+ 0.75^1 / (1! * (1 – 0.75))]$$

= 0.25

$P_5 = (0.75^5 * 0.25) / 1$
$P_4 = (0.75^4 * 0.25) / 1$
$P_3 = (0.75^3 * 0.25) / 1$
$P_2 = (0.75^2 * 0.25) / 1$
$P_1 = (0.75^1 * 0.25) / 1$

<u>P (n > 5)</u> = $1 – (P_0 + P_5 + P_4 + P_3 + P_2 + P_1)$
<u>= 17.8 %</u>

<u>Question 3</u>
3.6)
V = 120 km/h = 33.33 m/s
G_1 = 1%
G_2 = -2%
A = 3%

f = 0.28
SSD = $V_o t_{pr} + V_o^2 / (2 * g * f)$
= $33.33 * 2.5 + 33.33^2 / (2 * 9.81 * 0.28)$
= 285.5 m

$L_m = 2\ SSD - 200 * [\ sqrt(H_1) + sqrt(H_2)\ ]^2 / A$
= $2\ (285.54) - 200 * [\ sqrt(1.07) + sqrt(0.15)\ ]^2 / 3$
= 436.3 m
$L_m = A\ SSD^2 / [200 * (sqrt(H_1) + sqrt(H_2))^2]$
= $(3 * 285.54^2) / [200 * (sqrt(1.07) + sqrt(.15))^2]$
= 605.07 m

f = 1.4 * 0.28 = 0.392
t_{pr} = 1.2 * 2.5 = 3
SSD = 244.43 m
H_1 = 0.9 m
H_2 = 0.1 m
$L_m = 2 * 244.43 - 200 * [sqrt(0.9) + sqrt(0.1)]^2 / 3$
= 382.2 m
$L_m = (3 * 244.43^2) / [200 * (sqrt(0.9) + sqrt(0.1))^2]$
= 560.1 m

ΔL_m = 605.1 m – 560.1 m = 45 m

3.8)
Assume that the PVT for the sag curve will be the PVC of the crest curve.
$A\ L_s / 200 + A\ L_c / 200 = 7.5$ m
$K_s\ A^2 / 200 + K_c\ A^2 / 200 = 7.5$ m
For V = 80 km/h, K_s = 32 and K_c = 49
$32\ A^2 / 200 + 49\ A^2 / 200 = 7.5$
A = 4.3

L_s = KA = 32 * 4.3 = 36.3 m
L_c = KA = 49 * 4.3 = 210.7 m

Therefore the total length of road that has to be reconstructed is 70 + 2 * (36.3 + 210.7) = 564 m.

5.9) Using eq. 5.23

P(0) = 18/120 = 0.15 = $X^0 e^{-X}$ X = 1.90 veh/int.

0!

P(3) = $(1.90)^3 e^{-1.90}$ = 0.171

3! 120 int.(0.171) = 21 intervals

5.10)

λ = 1.90 veh/int = 0.95 veh/sec

20 sec/int

P(h>10) = $e^{-0.095(10)}$ = 0.387 or 38.7 %

P(h>6) = $e^{-0.095(6)}$ = 0.566 or 56.6 %

P(h<6) = 1 - P(h>6) = 1 – 0.566 = 0.434 or 43.4 %

5.29) D/D/1

λ = 4 veh/min at time = 0 min Departing does not begin until time = 30 min

D_t = 3,600 veh-min (area between arrival and departure curves) = ½ bh

b = 30 min, thus 3,600 = ½ (30)h and h = 240 veh

Dividing h by arrival rate, 240/4 = 60 min for the queue to dissipate.