Q1: What are the primary federal highway functional classifications? support your answer with a diagram that illustrate the hierarchy of a functional classification system for a rural area and the proportion of service provided by each functionally classified category.

Solution:

There are three primary federal highway functional classifications: arterial, collector, and local roads. All streets and highways are grouped into one of these classes, depending on the character of the traffic (i.e., local or long distance) and the degree of land access that they allow.

Arterial: Provides the highest level of service at the greatest speed for the longest uninterrupted distance, with some degree of access control. (provide direct service for cities and larger towns which generate and attract a large proportion of trips).

Collector: Provides a less highly developed level of service at a lower speed for shorter distances by collecting traffic from local roads and connecting them with arterials. (serve small towns directly and connect them to the arterial network. Collectors also collect traffic from local roads).

Local: Consists of all roads not defined as arterials or collectors; primarily provides access to land with little or no through movement. (the bottom level of the classification system, which serve individual farms and other rural land usage).

Table 2-1: Relationship between Functional Classification and Travel Characteristics

Functional Classification	Distance Served (and Length of Route)	Access Points	Speed Limit	Distance between Routes	Usage (AADT and DVMT)	Significance	Number of Travel Lanes
Arterial	Longest	Few	Highest	Longest	Highest	Statewide	More
Collector	Medium	Medium	Medium	Medium	Medium	Medium	Medium
Local	Shortest	Many	Lowest	Shortest	Lowest	Local	Fewer

The hierarchy of a functional classification system for a rural area is illustrated in figure 1.

The proportion of service provided by each functionally classified category is illustrated in figure 2.

Arterial networks emphasize a high level of mobility for through traffic movements. Local facilities emphasize more on the land access function. Collectors offer a compromise between both functions of land access and mobility.

Q2/What is a mass diagram? what the properties of it?

Certain characteristics of the mass curve must be understood before it can be used successfully. They are:

1. A *rising* mass curve denotes excavation at that point on the roadway; a *falling* curve denotes embankment. Where the roadway lies on a sidehill, the same cross section often shows both excavation and embankment. In such cases, a rising curve indicates an excess of excavation and a falling curve an excess of embankment.
2. Steep slopes of the mass curve reflect heavy cuts or fills; flat slopes indicate small earthwork quantities.
3. Points of zero slope on the mass curve represent points where the roadway goes from cut to fill, or vice versa. These low or high points on the mass curve may not come at the exact station at which the profile goes from cut to fill. There may be a net excess of excavation or embankment at this point if the cross slope is irregular.
4. The difference in ordinate between two points on the curve represents the net excess of excavation over embankment between those points, or conversely, the net excess of embankment over excavation.
5. If a horizontal line intersects the mass curve at two points, the excavation and embankment are in balance (equal in amount) between those points.

Q3/ define the term of the following :

a) **Street**
b) **Road**
c) **Haul**
d) **Borrow**
e) **Free haul distance**

- **Street**: is an urban road facility.
- **Road:** is a lower order facility designed for relatively lower speed and volume of traffic in the non-urban area.
- **Haul**: The distance over which material is transported, it is also used to describe the volume-distance of material moved.
- **Borrow**: Fill Materials that was not initially excavated from the project site.
- **Free haul distance**: The distance the contractor has agreed to move earth without additional fees.

Q4/ On a 4 lane highway with **3.6m** lane width It is proposed to design a circular curve for **80 Kph** speed. The station of TS is **5+530** and the station of ST is **5+880**. If The angle Δ_C is **33°** and **R>300m**. **Determine**:

1- The radius of the circular curve
2- The intersection angle between the two tangents
3- The station of a place at the exit to the curve, where the cross-slope is at **10%** of maximum superelevation**.**
4- The station of end of transition in the cross-slope at the exit of the curve.

Hint: bw=**0.75**, design super elevation = **0.02** and Maximum relative gradient is **0.005**

given R>300m we can assign the equation of LS for the problem

by solving all the equations we realise that LS= SQRT(24*0.2*R) has the optimum value of LS and can be used

st ST- st TS = 350 = CL+ 2*Ls = pi*33/180* R + 2*(24*0.2*R)$^{0.5}$

1- by solution we get R = 447m

ϴs = LS/24 R

2- $\Delta = \Delta_c + 2 * ϴs = 38.938$

3- station = station ST - 0.1*Ls = 5+875.368

4- station = station ST + LT where Lt = Ls as we can assume eNc = 2% = 5+926.321

Q5/ Complete the table below assuming the **shrinkage= 14%,** and determine the cost of anyeither **waste** or **borrow** volume if you know both cost **18 US$ per yard**, then plot the mass diagram on the graphic paper you have provided:

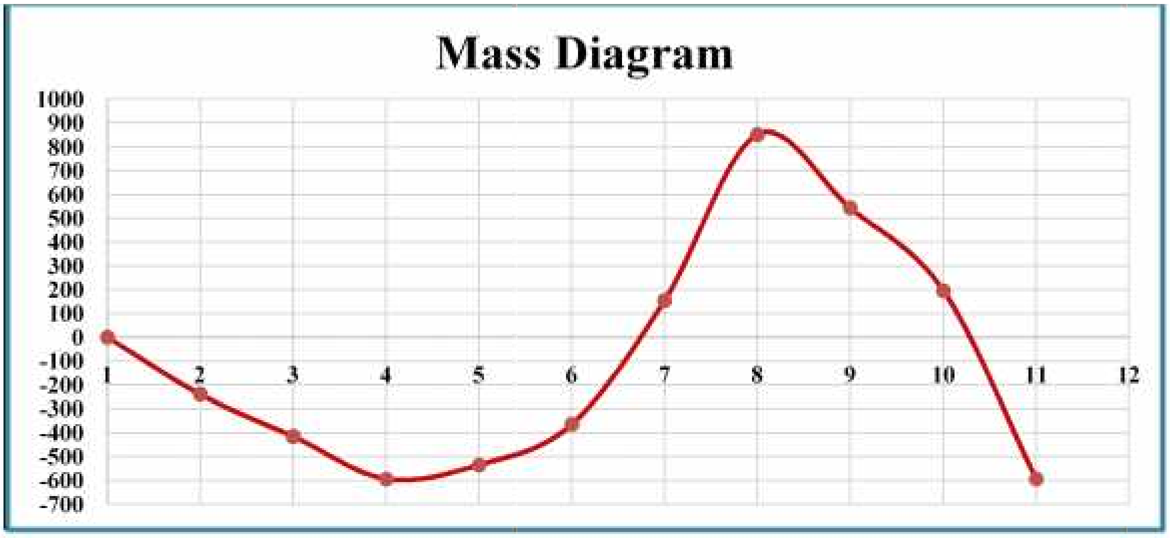
Stations	End Area ft²		Volume		Adjusted	Mass Diagram Ordinate
	Cut	Fill	Cut (yd)	Fill (yd)	Fill (yd)	
0+00		115				
0+50		112				
1+00		54				
2+00		30				
2+50	64					
3+00	120					
4+00	160					
5+00	217					
6+00		146				
6+50		183				
7+50		191				

Answer:

Stations	End Area ft²		Volume		Shrinkage 14%	Adjusted	Mass Diagram Ordinate
	Cut	Fill	Cut (yd)	Fill (yd)		Fill (yd)	
0+00		115		0	0		0
0+50		112		210	29	239	-239
1+00		54		154	22	176	-415
2+00		30		156	22	178	-593
2+50	64		59				-534
3+00	120		170				-364
4+00	160		519				155
5+00	217		698				853
6+00		146		270	38	308	545
6+50		183		305	43	348	197
7+50		191		693	97	790	-593

Total Fill Vol. – Total Cut Vol. = 2039 – 1446 = **593** yard (**Borrow**).

Cost of Borrow = 593 * 18 = 10,674 US$.



Q6/ What are the stages of constructing a highway?
Solution:
- Highway administration and finance
- Highway planning (20years)
- Economics
- Urban transportation planning
- Route location
- Acquisition of right-of-way
- Traffic engineering
- Earthwork
- Geometric design
- Structural design
- Drainage
- Contracts and specifications
- Highway maintenance
- Rehabilitation and evaluation

Q7/ What are the primary federal highway functional classifications? support your answer with a diagram that illustrate the hierarchy of a functional classification system for a rural area and the proportion of service provided by each functionally classified category.
Solution:

There are three primary federal highway functional classifications: arterial, collector, and local roads. All streets and highways are grouped into one of these classes, depending on the character of the traffic (i.e., local or long distance) and the degree of land access that they allow.
Arterial: Provides the highest level of service at the greatest speed for the longest uninterrupted distance, with some degree of access control. (provide direct service for cities and larger towns which generate and attract a large proportion of trips).
Collector: Provides a less highly developed level of service at a lower speed for shorter distances by collecting traffic from local roads and connecting them with arterials. (serve small towns directly and connect them to the arterial network. Collectors also collect traffic from local roads).
Local: Consists of all roads not defined as arterials or collectors; primarily provides access to land with little or no through movement. (the bottom level of the classification system, which serve individual farms and other rural land usage).

Table 2-1: Relationship between Functional Classification and Travel Characteristics

Functional Classification	Distance Served (and Length of Route)	Access Points	Speed Limit	Distance between Routes	Usage (AADT and DVMT)	Significance	Number of Travel Lanes
Arterial	Longest	Few	Highest	Longest	Highest	Statewide	More
Collector	Medium	Medium	Medium	Medium	Medium	Medium	Medium
Local	Shortest	Many	Lowest	Shortest	Lowest	Local	Fewer

The hierarchy of a functional classification system for a rural area is illustrated in figure 1.

The proportion of service provided by each functionally classified category is illustrated in figure 2.

Arterial networks emphasize a high level of mobility for through traffic movements. Local facilities emphasize more on the land access function. Collectors offer a compromise between both functions of land access and mobility.

Q8/ What the Purposes of Earthwork?

Solution:

- 1- to bring the sub-grade together with shoulders and slopes to the contours called for by the plans
- 2- to eliminate unsuitable materials from the sub-grade and from other portions of embankments and their foundations or to disperse such materials through the earth mass in such a manner that they will not be harmful.
- 3- to prevent saturation of soil in service or if the water cannot be eliminated, to neutralize any bad effects by the use of appropriate materials that are stable even when saturated.

Q9/ A 6 lane highway is designed for 90 kph speed. Two tangents intersect at the station of 24+00 on a certain place of the highway with an angle of intersection of 36°. It is proposed to design a circular curve between the two tangents with (0.01e+f) = 0.158, Determine:

1- The station of beginning of transition in the cross-slope at the entrance to the curve.

2- The length of the circular curve with full superelevation.

3- The station of a place at the exit to the curve, where the cross-slope is at 79% of the maximum superelevation (the elevation of that place is 450m at the centerline).

4- the elevation of the inner and outer edge of the cross-section at the place mentioned in point "3" above.

5- The stopping sight distance on the curve for a 10m middle ordinate.

Solution:

w=3.6m, n1=3, bw=0.67, f=0.13, ed=2.8%, Δ=0.47%, ϴ=36º, enc=2%

$R= V^2/(127(0.01e+f)) = 403.668m$

T= 131.160m CL=253.632m

Lr= W*n1*bw*ed/Δ = 43.108m

Lt = 30.791m

1- st IP - T - 2/3Lr - Lt = 2400 - 131.16 - 2/3*43.108 - 30.791 = 2+209.310

2- CL-1/3Lr - 1/3Lr = 224.893m

3- Station= st PT + 2/3Lr - 0.79Lr = 2+517.155

4- sin(tan^{-1} (2.8*0.79/100)) *3*3.6 = x = 0.239m

elevation inner = 450 - 0.239 = 449.761m elevation outer = 450+0.239 = 450.239m

5- M = R(1-cos(28.65*S/R)), M=10m so S= 180.064m

Q10/ If the volume after compaction was 1001 m3, the shrinkage factor and bulkingfactor were 0.909 and 1.009 respectively. Determine:

1- Volume of natural state soil

2- Volume of loose soil

3- Percentage of shrinkage

4- Percentage of bulking

volume after compaction= 1001 m^3

S.F.= 0.909 and B.F.= 1.009

1- S.F.= volume after compaction / volume before excavation

0.909 = 1001 / volume before excavation

so the volume of natural state soil = 1001/0.909 = 1101.21 m^3

2- B.F = volume after excavation / volume before excavation

1.009 = volume after excavation / 1101.21

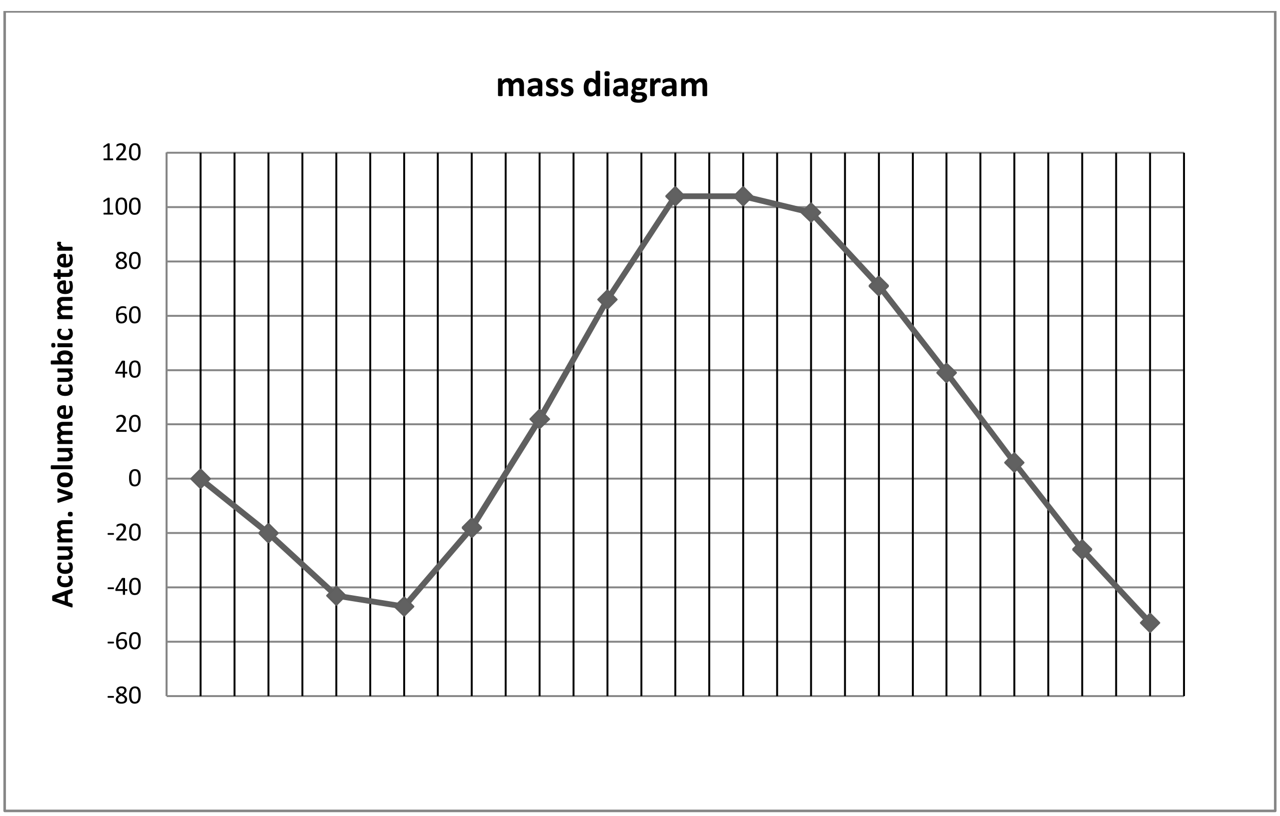
so the volume of loose soil = 1101.21*1.009 = 1111.121 m^3

3- % of shrinkage = 1 - S.F. = 9.1%

4- % of bulking = B.F. - 1 = 0.9%

Q11/ Given the mass diagram in figure 1 and if the free haul distance was 60m, calculate:

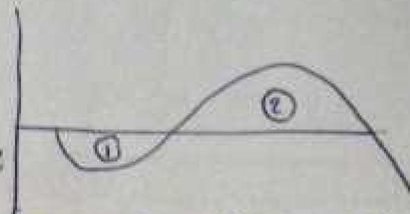
1- The haul distance 2- the overhaul distance 3- the overhaul and present full calculation process.



Problem 1:-

, = 3 Stations.

① Area of Zone ① for 60m free haul distance:



area of one pixel = 20 m³ x 20 m = 400 m³.m = 200 m³.m for one pixel
= 20 m³ x 1 station = 20 m³.st. = 10 m³.st. for one pixel

No. of pixels (complete) = 6 , incomplete pixles No. = 3

∴ total Area of Zone ① = 6×10 + 3/2 ×10 = 75 m³.st.

① - haul distance = 75/20 = 3.75 Stations , → height of under curve = 20 m³

② - over haul distance = 3.75 − 3 = 0.75 Stations = 15 m

- the over haul = 0.75 * 20 = 15 m³.st. = 300 m³.m.

Area of Zone ②

No. of complete pixels = 38 , incomplete No. = 20

total Area = 38× 10 + 20/2 ×10 = 380 + 100 = 480 m³.st.

① haul distance = 480/83 = 5.8 Stations → height = 83 m³

② - over haul distance = 5.8 − 3 = 2.8 Stations = 56m

- the over haul = 2.8 × 83 = 232.4 m³.st. = 4648 m³.m

~~1- the haul distance =~~

③ the over haul = 15 + 232.4 = 247.4 m³.st.
= 4948 m³.m

Q12/ A horizontal curve with R=245m is part of a 2-lane highway (3.8 each), and the minimum distance that large billboard can be placed from the centerline of the inside lane of the curve is 20m. Find the maximum speed in (Km/hr.) on the curve without reducing required SSD? Assume t=2.5 sec. and a=3.5m/s^2.

Solution:

Data: R=425m, Ms= 20m, t=2.5 sec, a=3.5m/s², Find V?

$$R_v = R - \frac{W}{2} \Rightarrow 245 - 3.8/2 = 243.1\text{m}.$$

$$SSD = \frac{\pi R_v}{90}\left[\cos^{-1}\left(\frac{R_v - M_s}{R_v}\right)\right]$$

$$SSD = \frac{\pi * 243.1}{90}\left[\cos^{-1}\left(\frac{243.1 - 20}{243.1}\right)\right]$$

$$SSD = 198.6m$$

Necessary data:

Design speed (km/h)	Maximum relative gradient (%)
60	0.60
70	0.55
80	0.50
90	0.47
100	0.44

Number of lanes rotated n	Adjustment factor b_w
1	1
1.5	0.83
2	0.75
2.5	0.7
3	0.67
3.5	0.64

Speed $_{Kph}$	50	60	70	80	100	120
Side friction, f	0.16	0.15	0.14	0.14	0.12	0.09

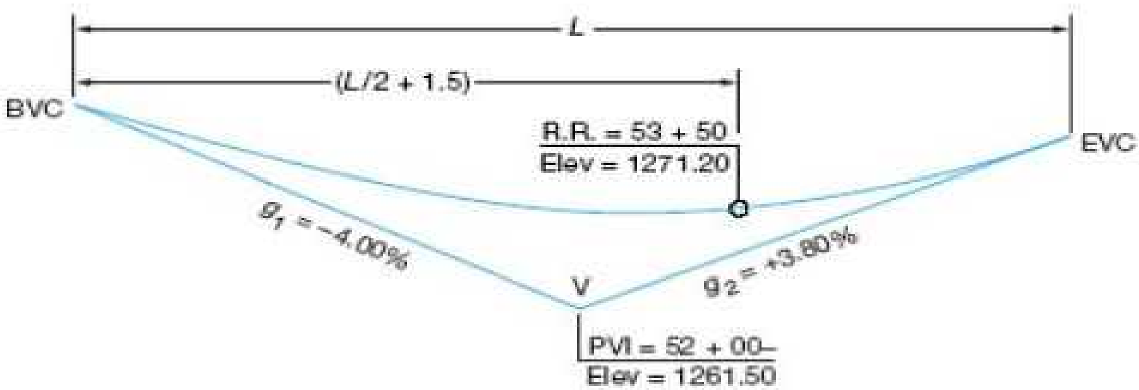
Speed kph	50	70	90	110
f_{max}	0.16	0.15	0.12	0.11
e_{max}	6.0%	8.2%	9.5%	11.0%

table: f_{max} and e_{max} for various speeds

Component of passing maneuver	Metric			
	Speed range (km/h)			
	50-65	66-80	81-95	96-110
	Average passing speed (km/h)			
	56.2	70.0	84.5	99.8
Initial maneuver:				
a = average acceleration[a]	2.25	2.30	2.37	2.41
t_1 = time (sec)[a]	3.6	4.0	4.3	4.5
Occupation of left lane:				
t_2 = time (sec)[a]	9.3	10.0	10.7	11.3
Clearance length:				
d_3 = distance traveled[a]	30	55	75	90

Exhibit 3-5. Elements of Safe Passing Sight Distance for Design of Two-Lane Highways

Q13/ Design an equal-tangent vertical curve to meet a railroad crossing which exists at STA 53 + 50 and elevation 1271.20'. The back grade (g1) of -4% meets the forward grade (g2) of +3.8% at PVI STA 52 + 00 with elevation 1261.50.



$$x = \frac{L}{2} + (5350 - 5200) = \frac{L}{2} + 150' = \frac{L}{2} + 1.5\, stations$$

$$y = y_{BVC} + g_1 x + \frac{r}{2}x^2$$

$$r = \frac{g_2 - g_1}{L}$$

$$Y_{BVC} = 1261.50 + 4.00\left(\frac{L}{2}\right)$$

$$g_1 x = -4.00x = -4.00\left(\frac{L}{2} + 1.5\right)$$

$$r = \frac{3.80 + 4.00}{L}$$

$$\frac{r}{2}x^2 = \frac{3.80 + 4.00}{2L}\left(\frac{L}{2} + 1.5\right)^2$$

$$1271.20 = \left[1261.50 + 4.00\left(\frac{L}{2}\right)\right] + \left[-4.00\left(\frac{L}{2} + 1.5\right)\right] + \left[\frac{3.80 + 4.00}{2L}\left(\frac{L}{2} + 1.5\right)^2\right]$$

$$0.975L^2 - 9.85L + 8.775 = 0$$

$$a = 0.975 \qquad b = -9.85 \qquad c = 8.775$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$L = 9.1152\,stations = 911.52'$$

L = 911.52'

Check by substituting **x** = $\left[\frac{9.1152}{2} + 1.5\right]$ **stations into the elevation equation to see if it matches a value of 1271.20'.**

Q14/ A horizontal curve with R=245m is part of a 2-lane highway (3.8 each), and the minimum distance that large billboard can be placed from the centerline of the inside lane of the curve is 20m. Find the maximum speed in (Km/hr.) on the curve without reducing required SSD? Assume t=2.5 sec. and a=3.5m/s^2.

Solution:

Data: R=425m, Ms= 20m, t=2.5 sec, a=3.5m/s^2,

Find V?

$$R_v = R - \frac{w}{2} = 245 - 3.8/2 = 243.1m.$$

$$SSD = \frac{\pi R_v}{90}\left[\cos^{-1}\left(\frac{R_v - M_s}{R_v}\right)\right]$$

$$SSD = \frac{\pi * 243.1}{90}\left[\cos^{-1}\left(\frac{243.1 - 20}{243.1}\right)\right]$$

$$SSD = 198.6m$$

$$SSD = 0.28\,Vt + \frac{0.039\,V^2}{a}$$

$$198.6 = 0.28\,V * 2.5 + \frac{0.039\,V^2}{3.5}$$

$$\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$V = +105.7\frac{Km}{hr} \quad or \quad V = -168.6\frac{Km}{hr}$$

So maximum speed is

$V = 105.7 \approx$ **??**

Q15/ A 4 lane highway with 3.6m lane width is designed for 100 kph speed. Two tangents intersect at the station of 3+700 on a certain place of the highway and The angle of intersection is 37°. It is proposed to design a circular curve without transition curves. If the elevation of station 3+580 is 420.2m at the centerline. Determine:

1- The remained length of the curve without full superelevation.

2- The elevation of inner and outer side of the road at station 3+580

3- The station of a place at the entrance to the curve, where the cross-slope is at 61% of the maximum superelevation.

4- The station of end of transition in cross-slope at the exit of the curve.

R= V^2/127(0.01e+f) = **539.3m**

Lr= W*n1*ed*bw/Δ   from table: Δ=0.44, bw=0.75, f=0.12 so ed=2.6%

Lr= 3.6*2*2.6*0.75/0.44 = **31.9m**

Lt= eNc/ed * Lr   assume eNc= 2%

Lt= 24.53m

T= R*tan (Θ/2)= **180.45m**

CL= R*Θ^{rad} = **348.26m**

1- Length = 1/3 *Lr + 1/3 *Lr = **21.3m**

2- at station 3+580 the superelevation is full, since the elevation of centreline is 420.2m

the elevation of inner side = 310.2- no. of lanes rotated * lane width* emax

= 420.2 - 2*3.6*0.026 = **420.0m**

the elevation of outer side = 420.2 + 2*3.6*0.026 = **420.4m**

3- required station = station of IP-T-2/3 * Lr +0.61*Lr = **(3+517)**

4- required station = station of IP-T+CL+2/3 * Lr + L t = **(3+914)**

Q16/ If the density after compaction is more than the density of natural state soil by 20%, the density after excavation is 1460 kg/m^3 and the percentage of bulking is 4% Determine**:** 1- Shrinkage factor. 2- Density of natural state soil. 3- Volume of excavation needed for 25m^3 of material. 4- Percentage of shrinkage. 5-Density after compaction.

Solution:

Problem 1/A/ Density after compaction is more than the density of natural state soil by 20%

Density after excavation = 1460 kg/m³

% of bulking = 4%

assume Density after compaction = A ⇒ $A = B + 20\% \text{ of } B = 1.2B$

assume Density of natural state soil = B

① Shrinkage factor $= \frac{B}{1.2B} = \frac{1}{1.2} = \boxed{0.833}$ (3m each)

② % of bulking = B.F. − 1 ⇒ 4% = B.F. − 1 ⇒ B.F. = 1.04

$B.F. = \frac{B}{1460} \Rightarrow 1.04 = \frac{B}{1460} \Rightarrow \boxed{B = 1518.4\ kg/m^3}$

③ volume of excavation needed $= 25 \frac{1}{S.F.} = \frac{25}{0.833} = \boxed{30\ m^3}$

④ % of shrinkage = 1 − S.F. = 1 − 0.833 = 0.167 = $\boxed{16.7\%}$

⑤ Density after compaction = 1.2B = 1.2 × 1518.4 = $\boxed{1822.1\ kg/m^3}$

Q17/Find the safe speed for a stopping sight distance of 87m on a 3.5% downgrade terrain**.**

Solution:

Metric	US Customary
$d = \frac{V^2}{254\left(\left(\frac{a}{9.81}\right) \pm G\right)}$	$d = \frac{V^2}{30\left(\left(\frac{a}{32.2}\right) \pm G\right)}$ (3-3)

The decision sight distances for avoidance maneuvers C, D, and E are determined as:

Metric	US Customary
$d = 0.278Vt$	$d = 1.47Vt$ (3-5)
where: t = total pre-maneuver and maneuver time, s (see notes in Exhibit 3-3); V = design speed, km/h	where: t = total pre-maneuver and maneuver time, s (see notes in Exhibit 3-3); V = design speed, mph

safe speed for SSD of 87m with down grade of 3.5%

$0.278V(2.5)+V^2/(254(3.4/9.81-3.5/100)) = 87$

V1 = +60kph V2= -115kph so safe speed = V1

Q18/ Find the passing sight distance for 90 kph design speed.

Solution:

The distance d_i traveled during the initial maneuver period is computed with the following equation:

Metric	US Customary
$d_1 = 0.278 t_i \left(v - m + \frac{a t_i}{2} \right)$	$d_1 = 1.47 t_i \left(v - m + \frac{a t_i}{2} \right)$ **(3-6)**
where: t_i = time of initial maneuver, s; a = average acceleration, km/h/s; v = average speed of passing vehicle, km/h; m = difference in speed of passed vehicle and passing vehicle, km/h	where: t_i = time of initial maneuver, s; a = average acceleration, mph/s; v = average speed of passing vehicle, mph; m = difference in speed of passed vehicle and passing vehicle, mph

Metric	US Customary
$d_2 = 0.278 v t_2$	$d_2 = 1.47 v t_2$ **(3-7)**
where: t_2 = time passing vehicle occupies the left lane, s; v = average speed of passing vehicle, km/h	where: t_2 = time passing vehicle occupies the left lane, s; v = average speed of passing vehicle, mph

Component of passing maneuver	Metric				US Customary			
	Speed range (km/h)				Speed range (mph)			
	50-65	66-80	81-95	96-110	30-40	40-50	50-60	60-70
	Average passing speed (km/h)				Average passing speed (mph)			
	56.2	70.0	84.5	99.8	34.9	43.8	52.6	62.0
Initial maneuver:								
a = average acceleration[a]	2.25	2.30	2.37	2.41	1.40	1.43	1.47	1.50
t_1 = time (sec)[a]	3.6	4.0	4.3	4.5	3.6	4.0	4.3	4.5
d_1 = distance traveled	45	66	89	113	145	216	289	366
Occupation of left lane:								
t_2 = time (sec)[a]	9.3	10.0	10.7	11.3	9.3	10.0	10.7	11.3
d_2 = distance traveled	145	195	251	314	477	643	827	1030
Clearance length:								
d_3 = distance traveled[a]	30	55	75	90	100	180	250	300
Opposing vehicle:								
d_4 = distance traveled	97	130	168	209	318	429	552	687
Total distance, $d_1 + d_2 + d_3 + d_4$	317	446	583	726	1040	1468	1918	2383

[a] For consistent speed relation, observed values adjusted slightly.

Note. In the metric portion of the table, speed values are in km/h, acceleration rates in km/h/s, and distances are in meters. In the U.S. customary portion of the table, speed values are in mph, acceleration rates in mph/sec, and distances are in feet.

Exhibit 3-5. Elements of Safe Passing Sight Distance for Design of Two-Lane Highways

from table, t1=4.3,a=2.37,t2=10.7,d3=75

d1 = 0.278*t*(V-m+a*t/2) = 95.746m

d2 = 0.278v*t2 = 267.714m

d3 = 75m

d4 = 2/3 *d2 = 178.476

PSD=d1+d2+d3+d4 = 616.936m

Q19/ A **6 lane** highway is designed for **90 kph** speed. Two tangents intersect at the station of **2+400** on a certain place of the highway with an angle of intersection of **36°**. It is proposed to design a circular curve between the two tangents **with (0.01e+f) = 0.158, Determine:**

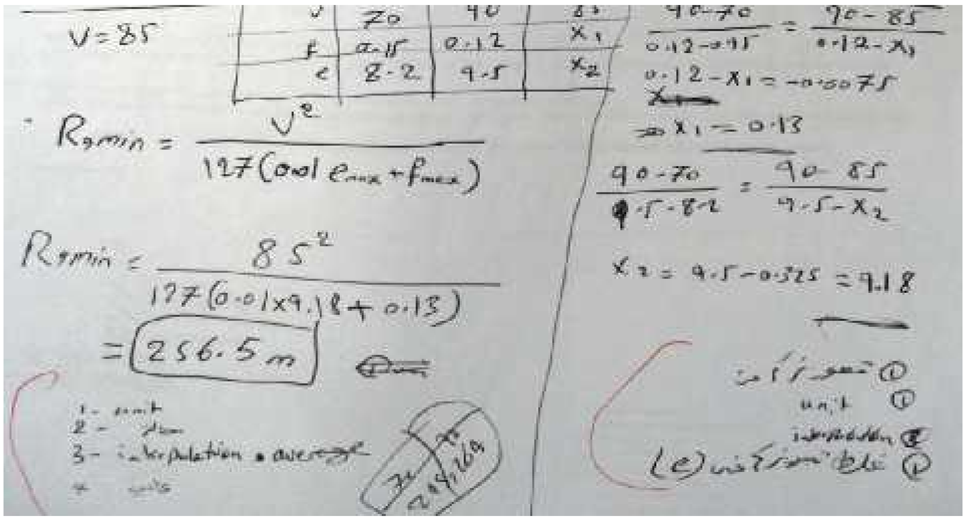
- Minimum radius of circular curve
- Superelevation Runoff length
- Tangent Runout length
- Station of P.C. & P.T.

Solution:

w=3.6m, n1=3, **bw=0.67**, **f=0.13**, ed=2.8%, **Δ=0.47%,** Ө=36º, **enc=2%**

R= $V^2/(127(0.01e+f))$ = 403.668m
T = R tan Ө/2=403.668*tan 36/2 = 131.160m
CL = Ө ***R=** (36*pi)/180*403.668=253.632m
Lr= W*n1*bw*ed/Δ = 43.108m
Lt = (enc/ed)*Lr=30.791m
PC=PI-T=
PT= PC+ CL =

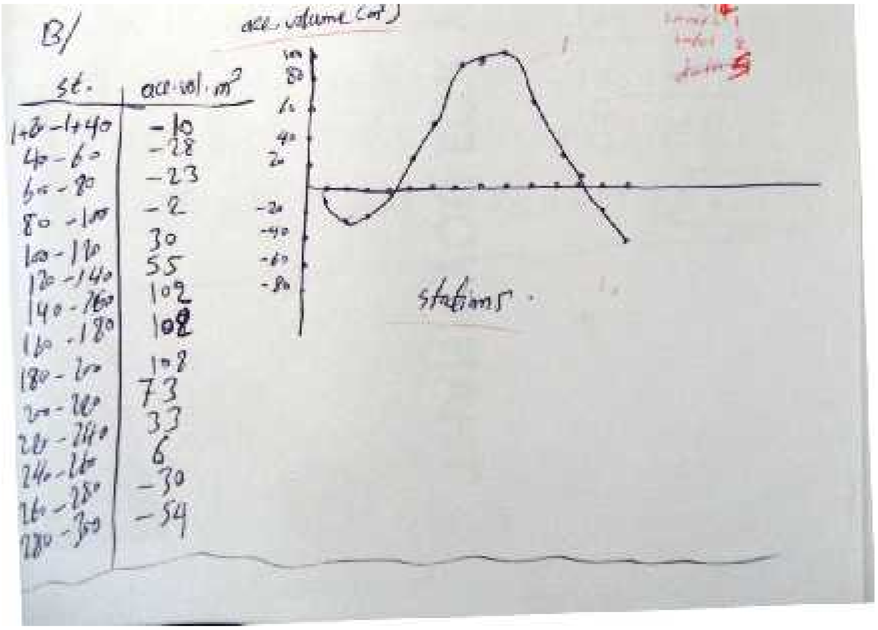
Q20/ Find the minimum radius of a horizontal curve on a highway for a design speed of 85 kph, when the f_{max} and e_{max} are controlling the minimum radius.
Solution:



Q21/ Draw the mass-haul diagram for the following earthwork volumes. Note: between stations 1+160 and 1+180 earthwork volume= 0 m^3 then draw an approximate profile that follow and coincide the mass-haul diagram.

Station	Excavation m^3	Embankment m^3	Station	Excavation m^3	Embankment m^3
1+20			1+180		
	0	10		12	6
1+40			1+200		
	0	18		0	35
1+60			1+220		
	7	2		0	40
1+80			1+240		
	21	0		0	27
1+100			1+260		
	32	0		0	36
1+120			1+280		
	25	0		0	24
1+140			1+300		
	47	0			
1+160					

Solution:



Q22/ A 4 lane highway with 3.7m lane width is designed for 90 kph speed. station of IP is 26+00. The angle of intersection is 35°. It is proposed to design a circular curve with transition curves. If the cross-slope at mid-way of spiral curve length is 1.5%. Lateral offset between tangent and circular curve = 5*Θ_s where Θ_s is in radians and by neglecting the equation of Ls_{max} for this problem, Determine: (20 Marks)

1- The radius of the curve (bigger value if applicable).
2- The station of a place at the exit to the curve, where the cross-slope is at 61% of the maximum superelevation.
3- The length at which the whole transition process is performed.

Use: Adjustment factor for number of lanes corrected is 0.75 and maximum relative gradient is 0.47%

Solution:

p = 5*Θ_s so $Ls^2/24R$ = 5* Ls/2R so Ls= 60m

to find R we need to see which equation is used

Ls= $(24*0.2*R)^{0.5}$ so R = 750m

Ls= $0.0214*V^3/RC$ C=1.2 default value so R= 217m

so R=750m

given at 50% of e_{design} slope is 1.5% so e_{design} = 3%

Lr= W*n1*ed*bw/Δ = 3.7*2*0.75*3/0.47 = 35.42m from table: Δ=0.47%, bw=0.75

Lt= eNc/ed * Ls = 3/2 * 60 = 90m assuming default value of 2% for eNc

Ts = (R+p)*tan (0.5*Δ) + Ls/2

Θ_s = Ls/2R = 2.29°

$\Delta_C = \Delta - 2\Theta_s$ = 30.42°

CL = 398.2m

Ts = 266.54m

station of place required = station of ST - 61/100 *60 = 2600 - 266.54 + 60*2 + 398.2 - 0.61*60 = 28+15.06

required length = 2Lt+2Ls+CL = 698.2m

Q23/ An equal tangent vertical curve is to be constructed between grades -4% initial and -1% final. The station of VPI is 12+800 and the elevation of VPI is 300m. There is a street crossing the road at station of 12+710 and the elevation must be 304m at that point. Find:

1- Elevation of VPC and VPT
2- Stopping sight distance

3- Safe speed on the curve

Solution:

a= (-1-(-4))/200L = 3/200L   A = 3

b= -0.04

c= 300+0.5*L*0.04 = 300+ 0.02L

$y = a*X^2 + b*X + c$

at station 12+710, the elevation is 304m

X = L/2 - (12800-12710) = L/2 - 90

$304 = 3/200L * (L/2-90)^2 - 0.04 (L/2-90) + (300+0.02L)$

solving the equation:

L1 = 382m, L2 = 85, so L = 382m because the curve is longer than 90m

1- elevation of VPC = elev. of VPI + L/2 *G1 = 307.64m

elevation of VPT = elev. of VPI - L/2 *G2 = 298.1m

2- assume S>L   so L = 2S - (120+3.5*S)/A   S= SSD = 506.4m

3- SSD = $0.278*V*t + 0.039*V^2/a$ ($a=3.4\ m/s^2$ and t=2.5 seconds)

V1 = 182 kph and V2 = -243 kph

so the safe speed is 182kph

Q24/ For intermediate semi-trailer WB-12, find the extra widening on a horizontal curve. Then find the distance to be cleared from the centerline of the highway to provide safe stopping sight distance, using the following data: 6- lane highway, V = 110 kph, R = 360m, Lane width = 3.7m. lateral clearance= 0.9m

solution:

6- lane highway, V = 110 kph, R = 360m, Lane width = 3.7m. lateral clearance= 0.9m

for WB-12 from table A= 0.9m, WB1=L= 3.8m, WB2= 8.4m, u=2.4m

N=2, C= 0.9m W_N= 2*3.7 = 7.4m

$Z = 0.1*V/R^{0.5} = 0.58m$

$F_A= (R^2 +A(2L+A))^{0.5} -R = 0.011$

$U=u+R-(R^2-\sum Li^2)^{0.5}$ here $\sum Li^2 = WB1^2+WB2^2$ U= 2.52m

$Wc= N(U+C)+(N-1)F_A+Z = 7.43$

$W= Wc-W_N$ = 7.43-7.4 = 0.03m for 2 lanes < 0.6m so use 0.6m

so total widening for 6 lanes = 0.6*3= 1.8m

* Distance to be cleared = M = R(1-cos(28.65*S/R)) $S=0.278*V*t + 0.039*V^2/a$ ($a=3.4\ m/s^2$ and t=2.5 seconds)

S = 215.2m   so the distance M = 16m

Q25/ Calculate the intersection sight distance along the major and minor roads, If an intersection is controlled by Stop sign. There is a grade of 3.5% on the minor road (downward). major road speed is 85 kph and minor road speed is 65 kph

Lanes:	Major Road	Minor Road
Left:	2 lanes	1 lanes
Right:	1 lane	1 lane
Cross:	2 lanes	1 lanes

Solution:

Case B

Case B1   tg from table =7.5s

correction for tg for multilane: 3*0.5 +tg = 9s   no correction for downgrade slope

a = 4.4m
b = 0.278*V*tg = 0.278*85*9 = 212.67m
Case B2:
a=4.4m
b= 0.278*V*(tg-1)   no correction for multilane and downgrade
b= 0.278*85*(7.5-1) = 153.60m
case B3:
no check required as the total number of lanes to be crossed is not greater than 6

Q26/ On a 4 lane highway with 3.6m lane width. It is proposed to design a circular curve for 80 Kph speed. The station of TS is 5+530 and the station of ST is 5+880. If the angle Δ_C is 33° and R>300m. Determine:
1- The radius of the circular curve
2- The intersection angle between the two tangents
3- The station of a place at the exit to the curve, where the cross-slope is at 10% of maximum superelevation.
4- The station of end of transition in the cross-slope at the exit of the curve.
Hint: bw=0.75, design super elevation = 0.02 and Maximum relative gradient is 0.005
Solution:
given R>300m we can assign the equation of LS for the problem
by solving all the equations we realise that LS= SQRT(24*0.2*R) has the optimum value of LS and can be used
st ST- st TS = 350 = CL+ 2*Ls = pi*33/180* R + 2*$(24*0.2*R)^{0.5}$
1- by solution we get R = 447m
ϴs = LS/24 R
2- $\Delta = \Delta_c$ + 2* ϴs = 38.938
3- station = station ST - 0.1*Ls = 5+875.368
4- station = station ST + LT where Lt = Ls as we can assume eNc = 2% = 5+926.321

Q27/ A 4 lane highway with 3.7m lane width is designed for 90 kph speed. Two tangents intersect at the station of 1+600 on a certain place of the highway and The angle of intersection is 35°. It is proposed to design a circular curve without transition curves at the beginning and the end of the circular curve. If the elevation of station 1+580 is 410.2m at the centerline. Determine:
1- The length of the curve with full superelevation only.
2- The elevation of inner and outer side of the road at station 1+580
3- The station of a place at the entrance to the curve, where the cross-slope is at 67% of the maximum superelevation. **Hint: (0.01e+f) = 0.146**
Solution:

Prob. 2 :

$e_{max} + f = e_d + 0.13 = 0.146$

$e_d = 1.6\%$

$$R = \frac{V^2}{127(e_{max} + f)} = \frac{90^2}{127 \times 0.146}$$

$$R = 436.846\,m$$

$$L_r = \frac{W\, n_1\, e_d}{\Delta} b_w$$

$$= \frac{3.7 \times 2 \times 0.75 \times 1.6}{0.47}$$

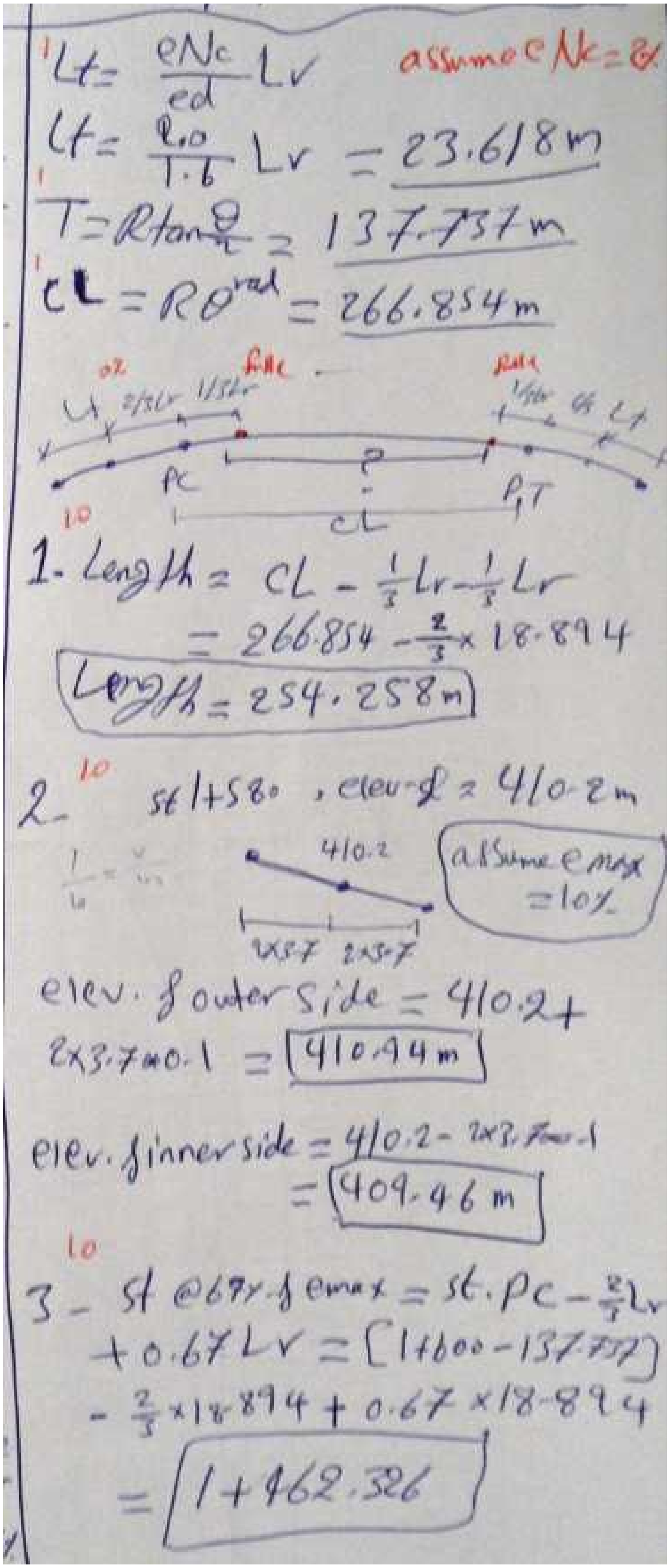
$$L_r = 18.894\,m$$

From table:

$b_w = 0.75$

$\Delta = 0.47$

$f = 0.13$



$L_t = \frac{e N_c}{e_d} L_r$ assume $e N_c = 2\%$

$L_t = \frac{2.0}{1.6} L_r = 23.618\,m$

$T = R \tan\frac{\theta}{2} = 137.737\,m$

$CL = R\theta^{rad} = 266.854\,m$

1- Length = $CL - \frac{1}{3}L_r - \frac{1}{3}L_r$
$= 266.854 - \frac{2}{3} \times 18.894$
Length = 254.258 m

2- st 1+580, elev. ℄ = 410.2 m

assume e_{max} = 10%

410.2

2×3.7 2×3.7

elev. of outer side = 410.2 + 2×3.7×0.1 = 410.94 m

elev. of inner side = 410.2 − 2×3.7×0.1 = 409.46 m

3- st @67% of e_{max} = st. PC $- \frac{2}{3}L_r + 0.67 L_r$ = [1+600 − 137.737] $- \frac{2}{3} \times 18.894 + 0.67 \times 18.894$
= 1+462.326

Q28/Calculate the intersection sight distance along the major and minor roads, if an intersection is controlled by FLASHING RED. There is a grade of 3.5% on the minor road (downward). Major road speed is 85 kph and minor road speed is 65 kph

Lanes:	Major Road	Minor Road
Left:	2 lanes	1 lanes

Right:	1 lane	1 lane
Cross:	2 lanes	1 lanes

Solution:

Flashing RED is like Case B

Case B1   tg from table =7.5s

correction for tg for multilane: 3*0.5 +tg = 9s   no correction for downgrade slope

a = 4.4m

b = 0.278*V*tg = 0.278*85*9 = 212.67m

Case B2:

a=4.4m

b= 0.278*V*(tg-1)   no correction for multilane and downgrade

b= 0.278*85*(7.5-1) = 153.60m

case B3:

no check required as the total number of lanes to be crossed is not greater than 6

Design vehicle	Time gap (s) at design speed of major road (t_g)
Passenger car	7.5
Single-unit truck	9.5
Combination truck	11.5