TRANSPORTATION ENGINEERING

REACTION TIME

$$S = vt + \frac{v^2}{2g(f \pm G)}$$

1. The driver of a car traveling at a certain speed suddenly sees an obstruction ahead and traveled a distance of 58.3 m during the perception time of 1.3 s. Determine the car's speed of approach in kph.
2. A car travelling at a speed of 65 mph approached a hazard and traveled 72.2 m during the perception-reaction time. What was the driver's PIEV? (Perception, identification, emotion and volition) time in seconds?
3. A car moving at 80 kph on a level ground suddenly sees an obstruction 76 m ahead. If the perception reaction time is 0.5 seconds and the coefficient of friction between the tires and pavement is 0.40, how far will the obstruction will it stop?
4. A driver traveling at 50 mph is 80 m from a wall ahead. If the driver applies the breaks immediately at a brake reaction time of 2 secs and begin slowing the vehicle at 10 m/s².
   a. Find the distance from the stopping point to the wall
   b. Determine the braking time or time during deceleration
   c. Assuming that the break efficiency of the vehicle is 70%, find the average skid resistance of the pavement.

MINIMUM RADIUS OF CURVATURE

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

(V is in kph here)

Degree of Curvature

$$D = \frac{1145.916}{R}$$

Impact Factor

$IF = \frac{V^2}{gR}$; V is in m/s

Ideal Angle of Embankment

$IF = \frac{V^2}{gR}$; V is in m/s

Max speed at which a car can round a curve without skidding

$\tan(\theta + \alpha) = \frac{V^2}{gR}$; V is in m/s

Where:
R = min radius of curvature
e = super elevation in m/m
f = coeff of side friction
D = degree of curvature
R = radius of curvature
g = 9.81 m/s²

θ = angle of embankment
tan α = μ

1. A highway curve has a super elevation of 7°. Find the radius of the curve so that there will be no lateral pressure between the tires and the roadway at the speed of 40 mph. *Ans. 265.71 m*
2. Compute the IF for a horizontal curve radius of 400 m if the design speed is 120 kph. *Ans 0.28*
3. A highway curve having a radius of 400 ft is banked so that there will be no lateral pressure On the car's wheel at a speed of 48 kph. What is the angle of elevation of the embankment? *Ans. 8.45°*
4. The rated speed of the highway curve of 100 m radius is 65 kph. If the coeff of friction between the tires and the road is 0.60, what is the maximum speed at which a car can round a curve without skidding? *Ans. 121. 795.*
5. When aligning a highway in a built up area, it was necessary to provide a horizontal circular curve of radius of 325 m. If the design speed is 65 kph, determine the super elevation rate. Note: Super elev fully counteracts centrifugal force use only 75% of the design speed. *Ans: e = 0.058*
6. Determine the radius of the horizontal curve for a design speed of 50 kph as specified by the specifications in lateral friction and super elevation. Note: f =0.15 inclination θ with the horizontal should not exceed 4°.
7. A pavement 12 m is to be super elevated to allow a safe navigation of a 2°30' circular curve at a design speed of 60 kph. What will be the theoretical difference in elevation between opposite edges of the pavement.

ACCIDENT RATES PER MILLION

Accident rate for 100 Million Vehicles per miles of travel in a segment of highway:

$$R = \frac{A(100{,}000{,}000)}{ADT \times N \times 365 \times L}$$

A= No. of Accidents during period of analysis
ADT = Average daily traffic
N= time period in years
L= Length of segment in miles

S= Severity Ratio= $\frac{fatal+injury}{fatal+injury+property\ damage}$

1. A 20 km stretch of highway had the following reported accidents:

YEAR	FATAL	INJURY	PROPERTY DAMAGE	ADT
1991	4	42	110	1000
1992	2	54	210	1200
1993	5	60	182	1250
1994	7	74	240	1300
1995	6	94	175	1350

   a. Find the severity ratio
   b. Determine the rate of injury accidents
   c. Compute the rate of total accidents

2. The number of accidents for 6 years recorded on a certain section of a highway is 5892. The average daily traffic is 476, what is the accident rate per million?

SPACE MEAN SPEEDS

$$U_s = \frac{\Sigma d}{\Sigma t} \; ; \; U_s = \frac{n}{\Sigma(\frac{1}{U_i})}$$

TIME MEAN SPEEDS

$$U_s = \frac{\Sigma \frac{d}{(t)}}{n} \; ; \; U_s = \frac{\Sigma U_i}{n}$$

Where:
Σt = sum of the time traveled by all the vehicles
Σd = sum of all the distances traveled by the vehicles
$\Sigma(\frac{1}{U_i})$ = sum of reciprocals of spot speed
ΣU_i = sum of all spot speed
n = no of vehicles

RATE OF FLOW

$Q = kU_s$

Q = rate of flow in veh/ hr
k = density in veh/km

U_s = space mean speed in kph

MINIMUM HEADWAY (hrs) = 1/C
SPACING OF VEHICLES (km) = 1/k
PEAK HOUR FACTOR (PHF) = q/q_{max}

1. The following data were observed for four vehicles traversing a distance of 2 mi segment of the Manila Coastal Road Project. It is required to compute the space mean speed of this vehicle.

Vehicle	Time (mins)
A	1.2
B	1.4
C	1.5
D	1.6

2. Five vehicles were traversing a 2 km highway and the following data were taken:

VEHICLE	TIME (mins)
1	1.8
2	1.4
3	1.6
4	1.5
5	1.3

a. Find the density of traffic in vehicles/ km
b. Find the space mean in kph
c. Compute the time mean speed in kph.

3. In a certain portion of highway, the recorded peak hour factor (PHF) during rush hour is 0.90. The highest 5 minute volume is 250 vehicles and the space mean speed is 90 kph.

a. Find the volume of traffic in vehicles per hour
b. Find the density of traffic in vehicles per km
c. Find the spacing of vehicles in m.

4. The table shows the 15 minute volume counts during the peak hour factor on an approach in an intersection

Time	Volume of Traffic
6:00-6:15 PM	375
6:15-6:30 PM	380
6:30 PM-6:45 PM	412
6:45-7:00 PM	390

Determine the peak hour factor.

VERTICAL SIGHT DISTANCES

A. For crest: SUMMIT CURVE
When S < L A= $g_1 - g_2$ in %

$$L = \frac{AS^2}{100\left(\sqrt{2h_1}+\sqrt{2h_2}\right)^2}$$

S > L A= $g_1 - g_2$ in %

$$L = 2S - \frac{200(\sqrt{h_1}+\sqrt{h_2})^2}{A}$$

If h is not given then:

h_1 = 1.08 m and h_2 = 0.60 m

$L = \frac{AS^2}{658}$ when S<L

$L = 2S - \frac{658}{A}$ when S>L

L= KA
K = Length of the vertical curve in meters for 1 % change of grade.

R = 100K
R = Radius of parabolic curves

California standards length for vertical curve: (sag and crest)

V< 60 kph ;	L= 60 m
A<2%;	L = 60 m
V>60 kph and A>2%;	L =2V
V>60 kph but A<2%;	L= 60 m

B. FOR SAG:

$$S < L : \; L = \frac{AS^2}{120+3.5S}$$

$$S > L : \; L = 2S - \frac{120+3.5S}{A}$$

Comfort Criterion:

$$L = \frac{AV^2}{395} \; ; V = \text{in kph}$$

C. UNDERPASS SIGHT DISTANCE

1. An ascending grade of 5% and descending grade of 4 % are connected by a parabolic curve. A motorist passing on the curve and whose eyesight is 1.5 m above the pavement could just see the top of a visible object 130 mm high at a horizontal distance of 160 m.
   a. Determine the length of parabolic curve connecting the grade lines
   b. Find the location of the summit from PT.
2. A +3.2% grade intersects a -2.8% grade. Design a parabolic curve that shall connect the two gradelines and will conform with the following sight distance specifications:
   Design Velocity = 80 kph
   Height of driver's eye = 1.7 m
   Height of object = 1.1 m
   Perception time = 0.75 s
   Coefficient of friction = 0.15

   a. Determine the sight distance
   b. Find the length of the parabolic curve

3. In a certain underpass, the length of the parabolic sag curve is 240 m. The height of the object at the instant of perception is 1.0 m and the driver's eye is 1.6 m above the road. The approach grade is -4% and the forward tangent is +2.4%. If the sight distance is 320 m.
   a. Determine the clearance at the center of the curve.
   b. Find the location from PC where the catch basin should be installed

4. A parabolic curve has the ff elements:
   a. The tangent grades are -1.8% and +2.2% respectively and the length of the curve is 135 m, compute the sight distance
   b. If the tangent grades are 3% and -2% respectively, compute the length of curve for a sight distance of 190 m.
   c. If the tangent grades are -1.7% and +2.3% respectively, determine the maximum speed in kph that a car could travel on this curve considering a sight distance of 150 m.

5. A vertical summit curve has tangent grade of +0.5% and -1.0 % grade for a road which will provide a stopping sight distance of 190 m. Height driver's eye above the pavement is 1.07 m and the height of the object ahead is 0.15 m. Compute the minimum length of a crest vertical curve for a design speed of 100 kph. *Use Lmin = 60 m*
6. A vertical parabolic curve has a sight distance of 130 m. The curve has tangent grades of +2.8% and -1.6 %. If the height of the driver's eye from the pavement is 1.08 m and the height of the object is 0.50 m.,
   a. Compute the max speed of the car that can pass thru the curve. *Ans. 60.69 kph*
   b. Compute the length of the vertical curve in meters for every 1% change of grade. *Ans: 27.59 m*
   c. Compute the equivalent radius of the vertical curve. *Ans: 2759 m*
7. Compute the minimum length of vertical curves that will provide 190 m stopping sight distance for a design speed of 110 kph at the intersection of a +3.5% grade and a -2.70% grade.
8. Compute the minimum length of a vertical sag curve that will provide 130 m stopping sight distance for a design speed of 80 kph at the intersection of a -2.30 % and +4.8% grade. *Ans: L= 115. 04 m*

SIGHT DISTANCE FOR HORIZONTAL CURVES

A. When S<L:

$$M = \frac{S^2}{8R}$$

M = clear distance from center of roadway to the obstruction
S = sight distance along the center of the roadway
R = radius of center-line curve
L = length of curve

B. When S>L:

$$M = \frac{L(2S-L)}{8R}$$

1. A highway curve has a radius of 80 m and a length of 90 m. If the reqd. sight distance is 60 m, how far off the center of the road could you allow the bushes to grow? *Ans: 5.625 m*
2. The clearance to obstruction is 40 m and the desirable sight distance when rounding a horizontal curve is 600 m. Determine the minimum radius of horizontal curve if the length of curve is 550 m long. *Ans: 1117.19 m*
3. A building is located 5.8 m from the centerline of the inside lane of a curve section of a highway with 120 m radius. The road is level. Perception reaction time is 2.5 s and coeff of friction is 0.35. Determine the appropriate speed limit in kph considering the stopping sight distance. *Ans: 56.25 kph*

HIGHWAY ENGINEERING

DESIGN OF PAVEMENT

1. **RIGID PAVEMENT WITHOUT DOWELS**

$$t = \sqrt{\frac{3W}{f}}$$

2. **RIGID PAVEMENT WITH DOWELS**

$$t = \sqrt{\frac{3W}{2f}} \quad \text{at the edge}$$

$$t = \sqrt{\frac{3W}{4f}} \quad \text{at the center}$$

t = thickness of pavement

W = Wheel Load
f = allowable tensile of concrete

3. **Flexible Pavement**

$$t = (0.564)\sqrt{\frac{W}{f1}} - r$$

f_1 = allowable bearing pressure of subgrade
r = radius of circular area of contact between wheel liad and pavement

4. **Thickness of pavement in terms of expansion pressure**

$$t = \frac{expansion\ pressure}{pavement\ density}$$

5. **Stiffness factor of pavement**

$$S.F. = \left(\frac{E_S}{E_P}\right)^{1/3}$$

1. Determine the thickness of pavement from the following conditions:
   1. The pavement is rigid and to carry a maximum wheel load of 60 kN. Neglect the effect of dowels. F'c = 20 MPa and use an allowable tensile stress of concrete pavement equal to 0.06f'c.
   2. The concrete pavement has an expansion pressure of 1.5 kg/cm^2 and the pavement density is 0.0025 kg/cm^3.
   3. A 53.5 kN wheel load has a max tire pressure of 0.62 MPa. This pressure is to be uniformly distributed over the area in contact on the roadway. Assuming a subgrade pressure not to exceed 0.14 Mpa , determine the required thickness of flexible pavement structure, according to the principle of the cone pressure distribution.

STIFFNESS FACTOR

1. What is the stiffness factor of pavement if its modulus of elasticity is 180 MPa and whose subgrade modolus is 40 MPa?