1. A car hits a tree at an estimated speed of 35 mi/h on a 3% downgrade. If skid marks of 100 ft are observed on dry pavement (F=0.45), followed by 250 ft (F=0.20) on a grass-stabilized shoulder, estimate the initial speed of the vehicle just before the pavement skid was begun.

   Solution:

   $$d_b(shoulder) = \frac{S^2(\text{shoulder}) - S^2(\text{hit})}{30(\text{F(shoulder)} - 0.01\text{G})}$$

   $$S^2(shouler) = 250 * 30 * (0.20 - 0.03) + 35 * 35(\text{mi/h})^2 = 2500\ (\text{mi/h})^2$$

   $$d_b(pavement) = \frac{S^2(\text{pavement}) - S^2(\text{shoulder})}{30(\text{F(pavement)} - 0.01\text{G})}$$

   $$\text{S(pavement)} = \sqrt{100 * 30 * (0.45 - 0.03) + 2500} = 61.32\ (mi/h)$$

2. What is the safe stopping distance for a section of rural freeway with a design speed of 80 mi/h on a 4% upgrade?

   Solution:

   $d_r = 1.47 * S * t$

   $$d_b = \frac{S^2}{30(0.348 + 0.01\text{G})}$$

   $d = d_r + d_b = 1.47*80*2.5+\frac{80^2}{30*(0.348+0.04)}$ ft = 294 + 549.83 ft = 843.83 (ft)

3. A highway reconstruction project is being undertaken to reduce accident rates. The reconstruction involves a major realignment of the highway such that a 60-mph design speed is attained. At one point on the highway, an 800-ft equal tangent crest vertical curve exists. Measurements show that, at 3 + 52 stations from the PVC, the vertical curve offset is 3 ft. Assess the adequacy of the existing curve in light of the reconstruction design speed of 60 mph and, if the existing curve is inadequate, compute a satisfactory curve length. (Consider both minimum and desirable SSDs.)

   Solution:

   For minimum SSD, the assumed average running speed is 52 mph from Table 3.1. The coefficient of friction is 0.29 from Table 3.1.

   $g = 32.2\ \text{ft/s}^2$

   t_r=2.5 s

   $Y = \frac{A}{200\text{L}} x^2$, $3=\frac{A}{200*800}352^2$, A=3.87

   $$SSD = \frac{{v_1}^2}{2\text{g}(\text{f}-\text{G})} + v_1\, t_r = \frac{(52*1.47)^2}{2*32.2*(0.29-0.0387)} + 52 * 1.47 * 2.5\, ft = 552.15\ \text{ft}$$

   SSD < L, $L_m = \frac{A(SSD)^2}{1329} = \frac{3.87*(552.15)^2}{1329}\, ft = 887.77$ ft

   Since 887.77 > 552.15, the assumption that SSD < L is valid.

For desirable SSD, the initial vehicle speed is assumed to be equal to the highway's design speed.

$$SSD = \frac{v_1{}^2}{2g(f-G)} + v_1\, t_r = \frac{(60*1.47)^2}{2*32.2*(0.29-0.0387)} + 60*1.47*2.5\,ft = 701.18 \text{ ft}$$

$$SSD < L,\ L_m = \frac{A(SSD)^2}{1329} = \frac{3.87*(701.18)^2}{1329}\,ft = 1431.68 \text{ ft}$$

Since 1431.68 > 701.18, the assumption that SSD < L is satisfied.

4. A horizontal curve is being designed through mountainous terrain for a four-lane road with 10-ft lanes. The central angle (Δ) is known to be 40°; the tangent distance is 510 ft; and the stationing of the tangent intersection (PI) is 2700 + 00. If the roadway surface has a coefficient of side friction of 0.082 and a superelevation of 0.09 ft/ft, determine the design speed and the stationing of the PC and PT.
Solution:
T = R*tan(Δ/2), 510 = R*tan(40*3.14/180/2), R = 1401.99 ft
D = 5729.6/R, L = 100Δ/D = 100ΔR/5729.6, L = 100*40*1401.99/5729.6 ft = 978.77 ft

design speed S = $\sqrt{15R(0.01e+f)} = \sqrt{15*1401.99*(0.09+0.082)}$ mi/h = 60.14 mi/h
stationing PC = 2700 + 00 – (5 + 10) = 2694 + 90
stationing PT = stationing PC + L = 2694 + 90 + 9 + 78.77 = 2704 + 68.77

5. A developer is having a single-lane raceway constructed with a 100-mph design speed. A curve on the raceway has a radius of 1000 ft, a central angle of 30 degrees, and PI stationing at 1125 +10. If the design coefficient of side friction is 0.2, determine the superelevation required at the design speed. Also, compute the degree of curve, length of curve, and stationing of the PC and PT?
Solution:
S = $\sqrt{15R(0.01e+f)}$, 100 = $\sqrt{15*1000*(0.01e+0.2)}$, e = 46.7
superelevation = 0.467 ft/ft

T = R*tan(Δ/2), T = 1000*tan(30*3.14/180/2) ft, T = 267.81 ft
stationing PC = 1125 + 10 – (2 + 67.81) = 1122 + 42.19

length of curve L = 100Δ/D = 100ΔR/5729.6, L = 100*30*1000/5729.6 ft = 523.60 ft
stationing PT = stationing PC + L = 1122 + 42.19 + 5 + 23.60 = 1127 + 65.79

6. Find the minimum length of curve for the following scenarios:

Entry Grade	Exit Grade	Design Speed	Reaction Time
3%	7%	55mi/h	2.5s
-5%	2%	60mi/h	2.5s
2%	-3%	70mi/h	2.5s

Solution:

Consider desirable SSD:

①

$$SSD = \frac{v_1{}^2}{2g(f+G)} + v_1\, t_r = \frac{(55*1.47)^2}{2*32.2*(0.30+0.03)} + 55 * 1.47 * 2.5\, ft = 509.71 \text{ ft}$$

$$L_m = 2SSD - \frac{1329}{A} = 2 * 509.71 - \frac{1329}{4}\, ft = 687.17 \text{ ft (SSD > L is unsatisfied)}$$

$$L_m = \frac{A(SSD)^2}{1329} = \frac{4*(509.71)^2}{1329}\, ft = 781.95 \text{ ft (SSD < L is satisfied)}$$

$L_m = 781.95$ ft

②

$$SSD = \frac{v_1{}^2}{2g(f-G)} + v_1\, t_r = \frac{(60*1.47)^2}{2*32.2*(0.29-0.05)} + 60 * 1.47 * 2.5\, ft = 723.82 \text{ ft}$$

$$L_m = 2SSD - \frac{1329}{A} = 2 * 723.82 - \frac{1329}{7}\, ft = 1257.78 \text{ ft (SSD > L is unsatisfied)}$$

$$L_m = \frac{A(SSD)^2}{1329} = \frac{7*(723.82)^2}{1329}\, ft = 2759.52 \text{ ft (SSD < L is satisfied)}$$

$L_m = 2759.52$ ft

③

$$SSD = \frac{v_1{}^2}{2g(f-G)} + v_1\, t_r = \frac{(70*1.47)^2}{2*32.2*(0.28-0.03)} + 70 * 1.47 * 2.5\, ft = 914.92 \text{ ft}$$

$$L_m = 2SSD - \frac{1329}{A} = 2 * 914.92 - \frac{1329}{5}\, ft = 1564.04 \text{ ft (SSD > L is unsatisfied)}$$

$$L_m = \frac{A(SSD)^2}{1329} = \frac{5*(914.92)^2}{1329}\, ft = 3149.28 \text{ ft (SSD < L is satisfied)}$$

$L_m = 3149.28$ ft

Consider minimum SSD:

①

$$SSD = \frac{v_1{}^2}{2g(f+G)} + v_1\, t_r = \frac{(48*1.47)^2}{2*32.2*(0.30+0.03)} + 48 * 1.47 * 2.5\, ft = 410.67 \text{ ft}$$

$$L_m = 2SSD - \frac{1329}{A} = 2 * 410.67 - \frac{1329}{4}\, ft = 489.09 \text{ ft (SSD > L is invalid)}$$

$$L_m = \frac{A(SSD)^2}{1329} = \frac{4*(410.67)^2}{1329}\, ft = 507.60 \text{ ft (SSD < L is valid)}$$

$L_m = 507.60$ ft

②

$$SSD = \frac{v_1{}^2}{2g(f-G)} + v_1\, t_r = \frac{(52*1.47)^2}{2*32.2*(0.29-0.05)} + 52 * 1.47 * 2.5\, ft = 569.15 \text{ ft}$$

$$L_m = 2SSD - \frac{1329}{A} = 2 * 569.15 - \frac{1329}{7}\, ft = 948.44 \text{ ft (SSD > L is invalid)}$$

$$L_m = \frac{A(SSD)^2}{1329} = \frac{7*(569.15)^2}{1329}\, ft = 1706.19 \text{ ft (SSD < L is valid)}$$

$L_m = 1706.19$ ft

③

$SSD = \frac{v_1{}^2}{2g(f-G)} + \; v_1\, t_r = \frac{(58*1.47)^2}{2*32.2*(0.28-0.03)} + 58*1.47*2.5\, ft = 664.66$ ft

$L_m = \; 2SSD - \frac{1329}{A} = 2*664.66 - \frac{1329}{5}\, ft = 1063.52$ ft (SSD > L is invalid)

$L_m = \; \frac{A(SSD)^2}{1329} = \frac{5*(664.66)^2}{1329}\, ft = 1662.05$ ft (SSD < L is valid)

$L_m = 1662.05$ ft