1.)

Eq.1. $$\boxed{R_{\min} = \frac{v^2}{g\left(e_{\max} + f_{s(\max)}\right)}}$$

$e_{max} = 0.1$, $f_{max} = 0.2$

$R_{min} = x = \frac{88^2}{32.2\ (0.1+0.2)} \approx 800$ ft

Design curve radius is 1.25 times the minimum allowable:

Use $R_{design} = 800 \times 1.25 = 1000$ ft

Apply the following equation to Calculate e_{design} using the design value of R:

Eq. 2. $$\boxed{e_{des} = \frac{v^2}{gR} - f_s \qquad for\ \ R > R_{\min}}$$

$e_{design} = \frac{88^2}{32.2 \times 1000} - 0.2 = 0.04$

From the Table 1, the minimum length of superelevation runoff for a two lane highway with 10-ft lanes is 175 ft. For a four-lane highway, use 1.5 times the minimum, that is about 265 ft.

Note: These results depend on the initial assumptions.

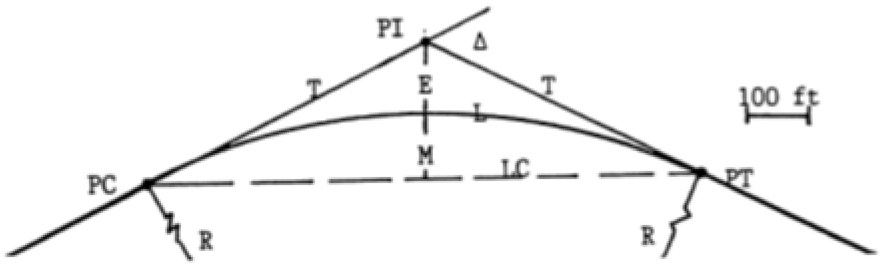
Table 1. Design Speed (MPh)

rate, *e*	20	30	40	50	55	60	65	70
				12-ft lanes				
0.02	50	100	125	150	160	175	190	200
0.04	60	100	125	150	160	175	190	200
0.06	95	110	125	150	160	175	190	200
0.08	125	145	170	190	205	215	230	240
0.10	160	180	210	240	255	270	290	300
0.12	195	215	250	290	305	320	350	360
				10-ft lanes				
0.02	50	100	125	150	160	175	190	200
0.04	50	100	125	150	160	175	190	200
0.06	80	100	125	150	160	175	190	200
0.08	105	120	140	160	170	180	190	200
0.10	130	150	175	200	215	225	240	250
0.12	160	180	210	240	255	270	290	300

Source: (From *A Policy on Geometric Design of Highways and Streets,* Copyright 1990, by the American Association of State Highway and Transportation Officials, Washington, DC [2.2] (Table III-15, p. 178.)

2.)

By use of Figure below and the following equations, calculate all the required parameters and sketch the center line plan.



Given $\Delta = 52^{\circ}$ and R = 1000 ft. From Eq. 3, calculate the degree of curve (D):

Eq. 3. $\boxed{D = \left(\dfrac{5729.58}{R(ft)}\right)^{\circ}}$ D = 5.73°

The length of tangent is also determined by use of Eq. 4.

Eq. 4. $\boxed{L = \dfrac{100\Delta}{D}}$ $L = \dfrac{100 \times 52}{5.73} = 907.5$ ft

$E = R\left(\sec\frac{\Delta}{2} - 1\right) = 1000\,(\sec 26^{\circ} - 1) = 112.6$ ft.

$M = R\left(1 - \cos\frac{\Delta}{2}\right) = 1000\,(1 - \cos 26^{\circ}) = 101.2$ ft.

$T = R\tan\frac{\Delta}{2} = 1000\tan 26^{\circ} = 487.7$ ft.

$LC = 2R\sin\frac{\Delta}{2} = 2 \times 1000\sin 26^{\circ} = 876.7$ ft.

D: Degree of curve (see text)

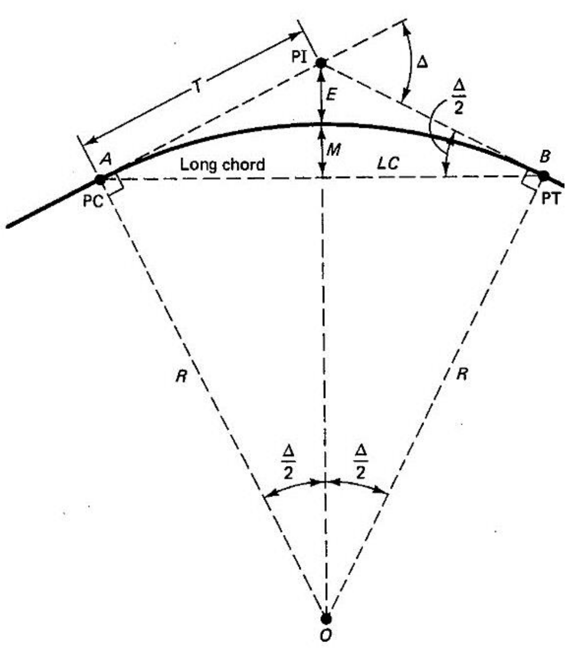
E: External distance = $R\left(\sec\dfrac{\Delta}{2} - 1\right)$

M: Middle ordinate distance = $R\left(1 - \cos\dfrac{\Delta}{2}\right)$

T: Length of tangent = $R\tan\dfrac{\Delta}{2}$

L: Length of curve = $100\dfrac{\Delta}{D}$

LC: Long chord = $2R\sin\dfrac{\Delta}{2}$



From the Exercise 1, the superelevation run off is 265 ft. Place about 30% (AASHTO) (approximately 80 ft) on the curve and the rest (185 ft) on the tangent. The width of the pavement on each side of the center line is (2 Lanes) (10 ft per lane) =20 ft.

At full superelevation the outside and inside edges are:

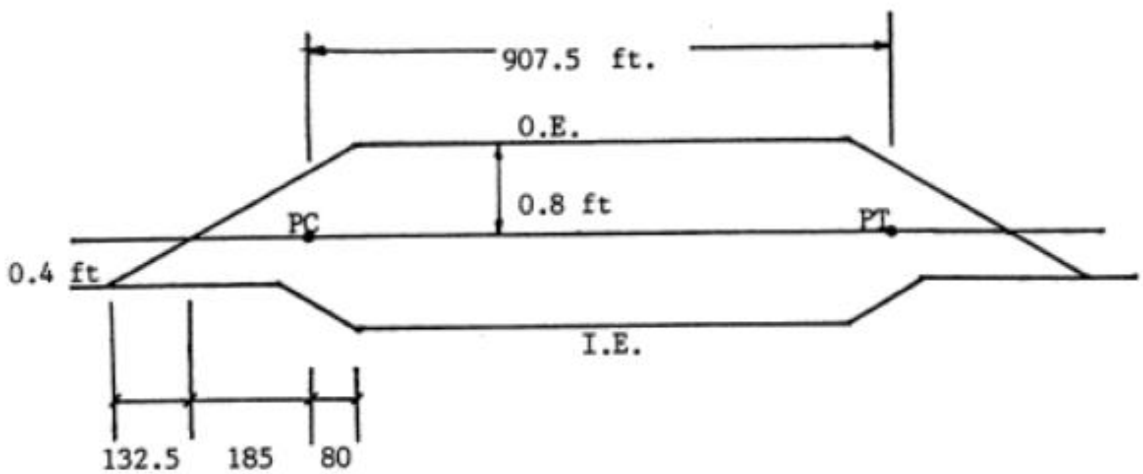
$20 \times d_{esign} = 20 \times 0.04 = 0.08$ ft (above and below the center line, respectively)

At normal crown, the two edges are:

$20 \times 0.02 = 0.4$ ft (below the center line)

From the similar triangles, the tangent runout is 132.5 ft.

The resulting longitudinal profile is:



3.)

The length of this crest vertical curve is 2000 ft or 20 - 100 ft stations. The VPC is located 10 stations before VPI (i.e., at sta. 42+60.55). Its elevation is:

VPC_{ele} = 0.03(L/2) = 30 ft (below the VPI, at 847.62 ft).

By similar reasoning, the VPT is located at sta. 62 + 60.55 and its elevation is as follows:

VPT_{ele} = 0.05(L/2) = 50 ft (below the VPI, at 827.62 ft).

The distance along the horizontal alignment from the VPC to the curve's high point is given by Equation below:

Eq.1. $\boxed{x = \frac{LG_1}{G_1 - G_2}(x \geq 0)}$ $x = \frac{2000 \times 3}{3-(-5)} = 750$ ft.

Therefore, the high point is at station (4260.55+ 750 = 5010.55 ft or 50+10.55).

To calculate the elevation of the high point, first calculate total change in grade (A) and external distance (E):

$A = G_2 - G_1 = -5 - 3 = -8$

$E = \frac{AL}{800} = -20$ ft (A = -8, and L =2000 ft)

The vertical offset of the high point is:

$Y = 4E(\frac{X}{L})^2 = 4(-20)(750/2000)^2 = -11.25$ ft.

Thus, using the Eq. 1, the elevation of the high point, when x = X = 750 ft, is equal to:

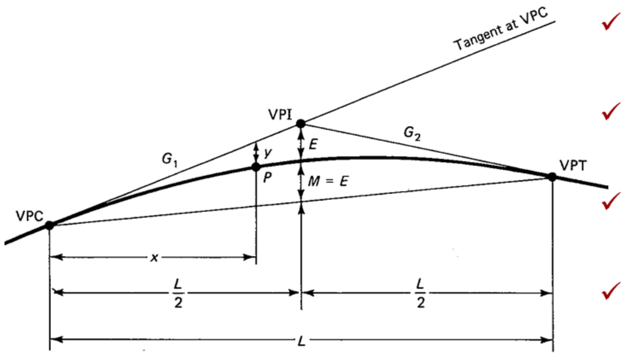
HP_{ele} = 847.62 + 0.03 (750) – 11.25 = 858.87 ft.

Station 54+00 is located at (5400.00 – 4260.55 = 1139.45 ft from the VPC). Its vertical offset is:

$y = 4(-20)(1139.45/2000)^2 = -25.97$ ft.

The curve elevation of sta. 54+00 can be determine by applying equation below:

Eq. 2. $\boxed{P_{ele} = \left[VPC_{ele} + \left(\frac{G_1}{100}\right)x\right] + y}$ P_{ele} = [847.62 + (3/100) 1139.45] -25.97 = 855.83 ft.



- ✓ **Total change in grade** $\boxed{A = G_2 - G_1 (\%)}$
- ✓ **Vertical curvature** $\boxed{K = \frac{L}{|A|}}$
- ✓ **External distance** $\boxed{E = \frac{AL}{800}}$
- ✓ **Offset *y*** $\boxed{y = 4E\left(\frac{x}{L}\right)^2}$
- ✓ **High (or low) point** $\boxed{x = \frac{LG_1}{G_1 - G_2} (x \geq 0)}$
- ✓ **Curve elevation**

$$\boxed{P_{ele} = \left[VPC_{ele} + \left(\frac{G_1}{100}\right)x\right] + y}$$