

Compute Values for a Parabolic Vertical Curve

Programmer: Dr. Bill Hazelton

Date: March, 2008. Version: 1.0

Mnemonic: P for Parabolic Vertical Curve.

Line	Instruction	Display	User Instructions
P001	LBL P		➤ LBL P
P002	CLSTK		➤ CLEAR 5
P003	FS? 10		⬅️ FLAGS 3 .0
P004	GTO P008		
P005	SF 1		⬅️ FLAGS 1 1
P006	SF 10		⬅️ FLAGS 1 .0
P007	GTO P009		
P008	CF 1		⬅️ FLAGS 2 1
P009	COMP V CURVE		(Key in using EQN RCL C, RCL O, etc.)
P010	PSE		➤ PSE
P011	CLx		➤ CLEAR 1
P012	STO S		➤ STO S
P013	STO R		➤ STO R
P014	STO Q		➤ STO Q
P015	STO P		➤ STO P
P016	STO A		➤ STO A
P017	STO L		➤ STO L
P018	ENTER P I RD		(Key in using EQN RCL E, RCL N, etc.)
P019	PSE		➤ PSE
P020	INPUT R	R?	⬅️ INPUT R
P021	ENTER P I EL		(Key in using EQN RCL E, RCL N, etc.)
P022	PSE		➤ PSE
P023	INPUT S	S?	⬅️ INPUT S
P024	START GRADE		(Key in using EQN RCL S, RCL T, etc.)
P025	PSE		➤ PSE
P026	INPUT P	P?	⬅️ INPUT P
P027	END GRADE		(Key in using EQN RCL E, RCL N, etc.)
P028	PSE		➤ PSE
P029	INPUT Q	Q?	⬅️ INPUT Q
P030	RCL Q		
P031	RCL - P		
P032	STO A		➤ STO A
P033	ENTER LENGTH		(Key in using EQN RCL E, RCL N, etc.)
P034	PSE		➤ PSE
P035	INPUT L	L?	⬅️ INPUT L
P036	RCL R		
P037	RCL L		
P038	2		
P039	÷		
P040	-		

HP-35s Calculator Program
Compute Values for a Parabolic Vertical Curve

Curves 2A

Line	Instruction
P041	STO U
P042	RCL S
P043	RCL P
P044	RCL× L
P045	2
P046	÷
P047	—
P048	STO V
P049	RCL A
P050	RCL÷ L
P051	2
P052	÷
P053	STO B
P054	RCL P
P055	RCL÷ B
P056	2
P057	÷
P058	+ / —
P059	STO I
****	Max/Min Pt. Data
P060	0
P061	STO Y
P062	MAX—MIN [0–1]
P063	PSE
P064	INPUT Y
P065	RCL Y
P066	$x \leq 0?$
P067	GTO P085
P068	RCL I
P069	x^2
P070	RCL× B
P071	RCL I
P072	RCL× P
P073	+
P074	RCL+ V
P075	STO E
P076	MAX—MIN EL
P077	PSE
P078	VIEW E
P079	MAX—MIN RD
P080	PSE
P081	RCL U

Line	Instruction
P082	RCL+ I
P083	STO D
P084	VIEW D
****	End Pts Data
P085	0
P086	STO Y
P087	END PTS [0–1]
P088	PSE
P089	INPUT Y
P090	RCL Y
P091	$x \leq 0?$
P092	GTO P116
P093	START PT RD
P094	PSE
P095	VIEW U
P096	START PT EL
P097	PSE
P098	VIEW V
P099	END PT RD
P100	PSE
P101	RCL U
P102	RCL+ L
P103	STO F
P104	VIEW F
P105	RCL L
P106	x^2
P107	RCL× B
P108	RCL L
P109	RCL× P
P110	+
P111	RCL+ V
P112	STO E
P113	END PT EL
P114	PSE
P115	VIEW E
****	Get EL from RD
P116	0
P117	STO Y
P118	STO X
P119	COMP 1 EL [0–1]
P120	PSE
P121	INPUT Y

Line	Instruction
P122	RCL Y
P123	$x \leq 0?$
P124	GTO P149
P125	ENTER RD
P126	PSE
P127	INPUT X
P128	RCL X
P129	RCL— U
P130	STO I
P131	x^2
P132	RCL× B
P133	RCL I
P134	RCL× P
P135	+
P136	RCL+ V
P137	STO H
P138	EL OF POINT
P139	PSE
P140	VIEW H
P141	0
P142	STO Y
P143	AGAIN [0–1]
P144	PSE
P145	INPUT Y
P146	RCL Y
P147	$x > 0?$
P148	GTO P125
****	Get RD from EL
P149	0
P150	STO Y
P151	STO H
P152	STO X
P153	COMP 1 RD [0–1]
P154	PSE
P155	INPUT Y
P156	RCL Y
P157	$x \leq 0?$
P158	GTO P224
P159	ENTER EL
P160	PSE
P161	INPUT H
P162	RCL V

**** These lines are simply comments in the code. You don't key it into the calculator!

HP-35s Calculator Program
Compute Values for a Parabolic Vertical Curve

Curves 2A

Line	Instruction
P163	RCL— H
P164	STO C
P165	RCL P
P166	x^2
P167	RCL B
P168	RCL× C
P169	4
P170	×
P171	—
P172	STO D
P173	$x < 0?$
P174	GTO P212
P175	$x = 0?$
P176	GTO P201
P177	RCL D
P178	\sqrt{x}
P179	STO D
P180	RCL— P
P181	RCL÷ B
P182	2
P183	÷
P184	RCL+ U
P185	STO X
P186	FIRST RD
P187	PSE
P188	VIEW X
P189	RCL D
P190	+/-
P191	RCL— P
P192	RCL÷ B
P193	2
P194	÷
P195	RCL+ U
P196	STO X
P197	SECOND RD
P198	PSE
P199	VIEW X
P200	GTO P216
P201	RCL P
P202	+/-
P203	RCL÷ B
P204	2
P205	÷
P206	RCL+ U

Line	Instruction
P207	STO X
P208	SINGLE RD
P209	PSE
P210	VIEW X
P211	GTO P216
P212	THIS ELEV
P213	PSE
P214	NOT ON CURVE
P215	PSE
P216	0
P217	STO Y
P218	AGAIN [0-1]
P219	PSE
P220	INPUT Y
P221	RCL Y
P222	$x > 0?$
P223	GTO P159
****	Step thru RDs
P224	0
P225	STO Y
P226	STO X
P227	STO H
P228	STO D
P229	STO C
P230	STO I
P231	STEP THRU RD
P232	PSE
P233	NO—YES [0-1]
P234	PSE
P235	INPUT Y
P236	RCL Y
P237	$x \leq 0?$
P238	GTO P313
P239	FIRST INCRMNT
P240	PSE
P241	INPUT C
P242	GENRL INCRMNT
P243	PSE
P244	INPUT D
P245	RD VALUE
P246	PSE
P247	VIEW U
P248	EL VALUE
P249	PSE

Line	Instruction
P250	VIEW V
P251	RD VALUE
P252	PSE
P253	RCL C
P254	RCL+ U
P255	STO X
P256	VIEW X
P257	RCL C
P258	x^2
P259	RCL× B
P260	RCL C
P261	RCL× P
P262	+
P263	RCL+ V
P264	STO H
P265	EL VALUE
P266	PSE
P267	VIEW H
P268	RCL C
P269	STO I
P270	RCL D
P271	STO+ I
P272	RCL I
P273	RCL— L
P274	$x > 0?$
P275	GTO P294
P276	RCL I
P277	x^2
P278	RCL× B
P279	RCL I
P280	RCL× P
P281	+
P282	RCL+ V
P283	STO H
P284	RCL I
P285	RCL+ U
P286	STO X
P287	RD VALUE
P288	PSE
P289	VIEW X
P290	EL VALUE
P291	PSE
P292	VIEW H
P293	GTO P270

HP-35s Calculator Program
Compute Values for a Parabolic Vertical Curve

Curves 2A

Line	Instruction
P294	END POINT
P295	PSE
P296	RCL L
P297	x^2
P298	RCL \times B
P299	RCL L
P300	RCL \times P
P301	+
P302	RCL+ V
P303	STO H
P304	RCL L
P305	RCL+ U
P306	STO X
P307	RD VALUE
P308	PSE
P309	VIEW X
P310	EL VALUE
P311	PSE
P312	VIEW H
****	End part
P313	PROGRAM END
P314	PSE
P315	FS? 1
P316	CF 10
P317	STOP
P318	RTN

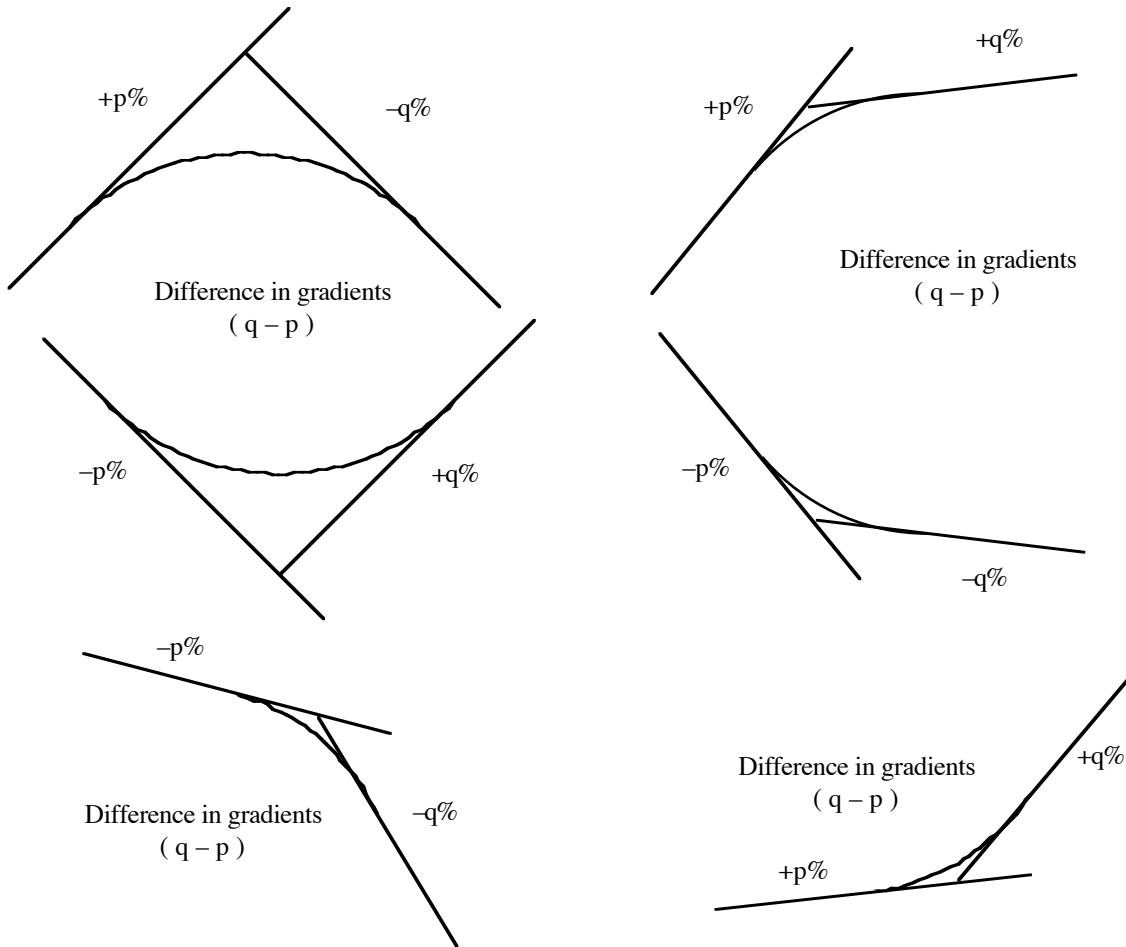
Notes

1. The **** lines are comments and are not to be entered into the calculator. They are there to make it easier to work through entering a long program.
2. The program offers options for the processing to be done at each step, asking the user if a particular set of operations are to be done. The user is prompted for a yes/no answer, with the input variable being Y, which is set to 0 (no) by default. To skip the operation, just press R/S. To do the operation, key in 1, then press R/S. The sense is that 0 = no, 1 = yes. Note that there is a need to pause after the prompt, otherwise the entered value will not make it into the calculator, and the 'no' response will be acted upon.
3. Because grades are used, it is important that the units for elevation and running distance are the same. Otherwise the computations will not be correct.
4. Some of the calculations will yield results that are on the parabola being used, but not within the actual segment being used. This is particularly the case with finding maximum and minimum points, which may not lie within the limits of the curve, and finding running distances given elevations. The user should check that the running distances fall within the

start and end points of the curve and ignore results that lie outside the curve. The program does not check these limits.

Theory and Background

The theory of computing the various values for a parabolic 'equal-tangent-length' vertical curve is fairly straightforward. There are six basic possibilities of how the vertical curve can be placed between two grade lines, as shown in the figure below. The curve allows the grade to be changed smoothly from the incoming grade (p) to the outgoing grade (q).



The convention with vertical curves is that they are drawn and computed going from left to right. If the grade is rising from left to right, the gradient is positive. If it is going down from left to right, the gradient is negative. The above diagram shows the signs that the various gradients would take in the circumstances.

If the grades on opposite sides of the curve have the same sign, as in the two examples in the right in the figure above, there is no maximum or minimum value along the curve (other than at its end points). If the grades have opposite signs (as in the two examples on the left side of the above diagram), then there will be a maximum or minimum point of the parabola somewhere along the

curve. In this case, the calculation of the elevation and location of such a point is meaningful. If such a calculation is made for the parabolas on the right in the diagram, the turning point for the parabola will be determined, but it will be well outside the part of the parabolic curve actually used. For example, the parabolas shown on the right side of the diagram above have their turning points well to the right of the end of the curve.

For the purposes of vertical curve design, parabolas are the preferred curve. They are simpler to compute than circles or ellipses, but differ from them by amounts that are too small to matter in almost all cases. With a parabola, there is a constant change of grade (or gradient) around the curve, whereas for a circle there is a constant change of angle around the curve.

Another useful characteristic of the parabola is that it can be placed so that the lengths of the tangents are always equal. As the tangents are usually close to level (grades usually being fairly small), the horizontal distances from the point of intersection of the two grade lines to the tangent points are equal, and half the length of the curve. This allows easy placement of the curve with respect to the point of intersection of the grade lines. [Note that if the in and out grades are not equal and of opposite sign, the maximum or minimum point will not fall directly below the intersection point.]

Gradients, Grades, Slopes and Angles

The slopes of the lines into and out of the vertical curve may be expressed in several ways. For this program, gradients should be entered as a decimal value of the gradient.

The gradient is the value of the change in elevation over a horizontal distance divided by that distance, i.e., rise over run, expressed as a decimal number. So, if the slope rises by 2 units for every 100 along, the gradient is $+2 \div 100 = +0.02$. If the slope falls by 5 units for 125 units along, the gradient is $-5 \div 125 = -0.04$.

The gradient can also be expressed as a percentage, which is simply the gradient value (as above) multiplied by 100 to convert it to a percentage. So the above examples would be +2% and -4%, respectively. Percentages are also handy in that they link in well to horizontal distances expressed in stations. As the distance is then in 100 ft units, a 1 foot rise would be a +1% grade, so the rise or fall over one 100 ft 'station' can be converted directly to the percentage gradient.

Gradients can also be expressed as a ratio of the rise to the run, and expressed in the form "1 in so many." To get this "so many" value, simply calculate the reciprocal value of the gradient (as a decimal), so for the two example given above, +0.02 would be $\frac{1}{0.02} = 50$, and so +1 in 50; -0.04 would be $\frac{1}{0.04} = 25$, and so -1 in 25.

Gradients can also be represented as the angle of the line from the horizontal, usually given in decimal degrees. The tangent of this angle will be the gradient, and the gradient can be converted to an angle by taking the arctangent of the gradient. So a gradient of +0.02 will give an angle of $\arctan(+0.02) = +1.146^\circ$, while -0.04 will give an angle of $\arctan(-0.04) = -2.291^\circ$. A slope of 1° would give a gradient of $\tan(1^\circ) = 0.017$.

Grade and gradient are used interchangeably, although sometimes they are applied to specific representations. For this program, convert all gradients to the decimal format, e.g., +0.02, -0.04. Be aware that the sign of the gradient is very important and **must** be included.

The term 'slope' is also used, but it usually doesn't refer to a specific representation.

Horizontal Distances

Horizontal distances as used in the construction of linear objects are commonly expressed as a distance from a starting point somewhere along the object. How they are expressed depends upon the units being used, the country in which they are being used, and local practice. Similarly, what they are called also varies.

Distances in feet are commonly recorded as 'station' values. Here, it is assumed that a station is marked every 100 ft, and that the stations are numbered sequentially from the start, with distances on from the station noted as additional distance. So a distance of 12,546.78 ft would be recorded as 125 + 46.78, meaning 125 stations of 100 feet, plus 46.78 feet past that station. For many construction projects, having points every 100 ft (30.48 m) is very convenient, hence the popularity of this representation. It is easy to convert between the distance representation (12,546.78 ft) and the station representation (125 + 46.78): simply remove the + sign and place the digits together to go to distance, or open the digits two left of the decimal point and put in a +, to convert to stations. (Calculators prefer the distance version.)

With metric units, 100 m is a bit long for station placement, so an equivalent metric representation never really caught on. In metric, it is more usual to use the distance representation (in meters) for all uses. This is also simpler as surveying moves away from the reliance on short lines for set-out (greatly aided by a station every 100 ft), to total station based set-out by co-ordinates across large areas.

The distances are known as 'stations' (when working with the 100 ft units), but this is a little odd when using a distance representation. In this case, the distance may be known as the 'Running Distance' (abbreviated RD), or the 'chainage' in some circumstances. As the station representation is so easily converted to the distance representation, and this program can also be used for metric applications, the horizontal distances in this program will be termed 'Running Distances' and often noted as RD.

Calculating The Parabola

The general equation of a parabola is:

$$y = ax^2 + bx + c$$

The magnitude of the term a controls the sharpness of the parabola, while the sign of a controls the orientation. With a positive, the parabola is turned upwards and is bowl-shaped (the apex or turning point is the smallest y value), while with a negative, the parabola is hill-shaped, with the apex having the largest y value. So a summit or crest has a negative a , while a sag has a positive a .

It is convenient to use the starting point of the parabola (i.e., the first or left-most tangent point) as the origin of the co-ordinates. The elevation of this point (A on the diagram overleaf) above the chosen datum is equal to the term c in the equation. The slope $\frac{dy}{dx}$ of any tangent is equal to $2ax + b$. But as at Point A , $x = 0$, the term b in the general equation is the slope or gradient at point A , the tangent gradient p .

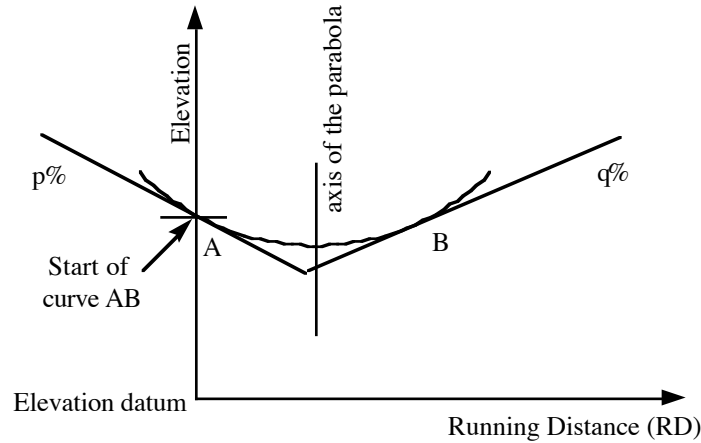
HP-35s Calculator Program
Compute Values for a Parabolic Vertical Curve

The second derivative $\frac{d^2y}{dx^2}$ of the general parabola equation equals $2a$, a constant. This means that a tangent to a vertical-axis parabola changes a constant amount of *grade* for each increment of distance. (In contrast, a tangent to a vertical circular curve changes direction a constant amount of *angle* for equal increments of distance along the arc.) The useful consequence is that the rate of change of grade on a vertical curve is constant and equals $2a$ per 100 units of distance (feet or meters, depending upon the units chosen). On a vertical curve the total change in direction between the profile grades is $q - p$, termed A .

If this change is accomplished on a curve L units long, the constant rate of change must be:

$$2a = \frac{q - p}{L} = \frac{A}{L}$$

with gradients q , p and A in decimal form, and L in either feet or meters, consistent with the job.



A practical formula for a general parabola for a vertical curve is therefore

$$\text{Elevation} = a (\text{RD} - \text{RD}_A)^2 + p (\text{RD} - \text{RD}_A) + \text{Elevation}_A$$

where RD is the running distance of any point, RD_A is the running distance of point A , a is the first parameter of the parabola (half the rate of change of grade as a decimal), p is the slope of the entry (or incoming) tangent (in decimal form), Elevation is the elevation of the point at running distance RD , and Elevation_A is the Elevation of point A . Elevation and RD should be in the same units, consistent with the entire job.

The location of the turning point of the parabola (the apex) can be computed by noting that the slope of the tangent at the turning point is 0, and solving $2ax + b = 0$. In this case, the location of the turning point is: $x = \frac{-b}{2a}$. This value can be converted to a running distance by adding the value of RD_A , and then used in the equation to compute the elevation of the maximum or minimum point on the curve.

HP-35s Calculator Program Compute Values for a Parabolic Vertical Curve

Curves 2A

Given the Elevation of a point on the curve, its location, x , from Point A can be computed by solving the equation:

$$a x^2 + p x + (\text{Elevation}_A - \text{Elevation}) = 0$$

As this is a quadratic, the standard quadratic solution will produce two solutions (in most cases), and it is up to the user to decide which is the most applicable. The program deals with the various cases (0, 1 and 2 solutions) separately. If there is a single solution, the apex (or nadir) of the curve has been selected. If there are no solutions, then the elevation selected is beyond the turning point elevation of the curve and therefore cannot lie on the curve.

For determining the elevations at set distances along the curve, the user can specify an initial increment, to bring the steps onto an even running distance, then specify a general increment, which will be used for the remainder of the curve. The program calculates the elevation of the first point on the curve (the left-hand tangent point), then moves along the initial increment, then proceeds along the curve using steps of the general increment, until the end of the curve is reached. The final point on the curve (the right-hand tangent point) is calculated and the program ends. For each point, the running distance and elevation are shown.

Note that if the final point calculated by increments happens to also be the end point, it will be calculated and displayed, and then the end point will be calculated again and displayed. This is because the test for coming to the end of the curve is that the increment is beyond the end point.

Running the Program

Key in XEQ P then press the Enter key. The program starts and displays:

```
COMP V CURVE
```

then prompts for the running distance of the intersection point of the two grade lines, displaying:

```
ENTER P I RD
```

then stops while displaying:

```
R?  
0.0000
```

Key in the RD of the intersection point and press R/S. The calculator then prompts for the elevation of the intersection point of the two grade lines, displaying:

```
ENTER P I EL
```

then stops while displaying:

```
S?  
0.0000
```

Key in the elevation of the intersection point, then press R/S. The calculator then prompts for the starting grade (p), displaying:

HP-35s Calculator Program
Compute Values for a Parabolic Vertical Curve

Curves 2A

START GRADE

then stops while displaying:

P?
0.0000

The value of the slope coming in to the vertical curve should be entered as a decimal value, e.g., 0.025 (an upward 2.5% gradient), then press R/S. The calculator then prompts for the grade coming out of the vertical curve, displaying:

END GRADE

then stops while displaying:

Q?
0.0000

Key in the value of the slope of the grade coming out of the curve, as a decimal grade, e.g., -0.04 (a downward 4% gradient), then press R/S. The calculator then prompts for the length of the curve, briefly displaying:

ENTER LENGTH

then stops while displaying:

L?
0.0000

Key in the length of the curve desired and press R/S.

From this point on, the program asks if the user wants to do optional computations. These options are presented in the order that follows, and any or all of them may be skipped or run.

A. *Maximum / Minimum Point*

The calculator display RUNNING briefly, then prompts for whether or not to calculate the point on the (whole) parabola where the maximum or minimum elevation occurs. If the vertical curve is a crest or sag, the maximum or minimum point will occur on the actual curve segment. If the in and out grades have the same sign, the maximum or minimum point will not be on the actual curve segment, so this option can be skipped. The calculator briefly displays:

MAX-MIN [0-1]

then stops and displays the prompt:

Y?
0.0000

The 0 means 'no' to the question of whether to run this option, and is the default response. If you don't want to run this option, press R/S and the program will advance to the next option. If you

HP-35s Calculator Program
Compute Values for a Parabolic Vertical Curve

Curves 2A

do want to run this option, key in 1 (or any number greater than 0), which signifies 'yes,' and press R/S. The calculator briefly displays:

MAX-MIN EL

then stops and displays the Elevation of the maximum or minimum point, looking as follows:

E=
114.5611

Press R/S to continue. The calculator then briefly displays:

MAX-MIN RD

then stops and displays the Running Distance of the maximum or minimum point, looking as follows:

D=
24,589.2222

Press R/S to continue, and this option concludes.

B. Compute the End Points

This option computes the running distance and elevation of the end points of the curve, where the parabolic curve joins the tangent gradients. The calculator briefly displays:

END PTS [0-1]

then stops and displays the prompt:

Y?
0.0000

If you don't want to run this option, press R/S and the program will advance to the next option. If you do want to run this option, key in 1 (or any number greater than 0), which signifies 'yes,' and press R/S. The calculator briefly displays:

START PT RD

then stops and display the running distance of the start point of the curve, such as follows:

U=
24,367.0000

Press R/S to continue. The calculator briefly displays:

START PT EL

then stops and displays the elevation of the start point of the curve, such as follows:

V=

HP-35s Calculator Program
Compute Values for a Parabolic Vertical Curve

Curves 2A

103.4500

Press R/S to continue. The calculator briefly displays:

END PT RD

then stops and display the running distance of the end point of the curve, such as follows:

F=
24,767.0000

Press R/S to continue. The calculator briefly displays:

END PT EL

then stops and displays the elevation of the end point of the curve, such as follows:

E=
107.4500

Press R/S to continue, and the option ends.

C. *Compute Elevation at a Specified Running Distance*

With this option, the user can enter any running distance and the calculator will compute the elevation on the curve at that point. The calculator does not check if the running distance is on the curve segment actually being used, so the user must check this. The calculator briefly displays:

COMP 1 EL [0-1]

although the right-hand bracket will be off screen. The calculator then stops and displays:

Y?
0.0000

If you don't want to run this option, press R/S and the program will advance to the next option. If you do want to run this option, key in 1 (or any number greater than 0), which signifies 'yes,' and press R/S. The calculator briefly displays:

ENTER RD

then stops and prompts for the RD to be entered, displaying:

X?
0.0000

Key in the running distance of the point of interest and press R/S. The calculator then briefly displays:

EL OF POINT

then stops and displays the elevation value of the selected point, such as follows:

HP-35s Calculator Program
Compute Values for a Parabolic Vertical Curve

Curves 2A

H=
114.3690

Press R/S to continue, and the calculator prompts to see if you want to compute another elevation, briefly displaying:

AGAIN [0-1]

then stopping and displaying:

Y?
0.0000

If you want to do another point, key in 1 and press R/S. The program then prompts for the running distance (as above) and loops through the option until you decide not to do it again. If you don't want to do this option, press R/S, and the option ends.

D. Compute the Running Distances at a Specified Elevation

This option allows the user to enter an elevation and compute the running distance(s) at which it occurs. Since the curve is a parabola, there will be zero, one or two solutions. If the elevation cannot occur on the curve, i.e., the elevation is beyond the elevation of the turning point of the parabola, there will be zero answers.

If the elevation chosen is that of the turning point, there will be just one answer, which will be provided. Any other elevation on the curve will have two solutions, and each will be given.

The calculator briefly displays:

COMP 1 RD [0-1]

with the right-hand bracket off the screen. The calculator then stops and displays the prompt:

Y?
0.0000

If you want to skip this option, just press R/S and the calculator moves on to the next option. If you do want to run this option, key in 1 and press R/S. The calculator briefly displays:

ENTER EL

then stops and displays:

H?
0.0000

Key in the elevation of interest, and press R/S.

If the elevation is not on the curve, the calculator briefly displays:

THIS ELEV

HP-35s Calculator Program
Compute Values for a Parabolic Vertical Curve

Curves 2A

then

NOT ON CURVE

and then prompts to see if you want to run the option again.

If the elevation is at the maximum or minimum point, the calculator briefly displays:

SINGLE RD

then stops and displays the running distance of the point, such as follows:

X=
24,392.9180

Press R/S/ to continue and the calculator prompts to see if you want to run the option again.

If the elevation is elsewhere on the curve, the calculator briefly displays:

FIRST RD

then stops and displays the running distance of the first solution point, such as follows:

X=
24,383.0819

Press R/S and the calculator briefly displays:

SECOND RD

then stops and displays the running distance of the second solution point, such as follows:

X=
24,795.3625

It is up to the user to decide if the points fall within the end points of the curve, and chose points that are useful.

Press R/S to continue, and the calculator then briefly displays:

AGAIN [0-1]

then stops and displays:

Y?
0.0000

To run the option again, key in and 1 and press R/S. The calculator will then prompt for the elevation to be entered, as above, and run through the option again. If you don't want to run the option again, press R/S and the option ends.

E. Step Through a Series of Running Distances to get Elevations at each

The final option allows the user to step through a series of equally-spaced points along the curve. As the start point is often at an odd running distance, this option allows the user to select a first increment, to allow the running distances to be brought to even values (e.g., exactly onto 100 ft stations), and then select a general increment to be applied successively until the end point is reached. The end point is calculated as the last point along the curve.

The option begins by displaying briefly:

STEP THRU RD

then displaying briefly:

NO-YES [0-1]

then stopping and displaying:

Y?
0.0000

If you want to run this option, key in 1 and press R/S. If not, just press R/S and the program ends. If you are running the option, the calculator briefly displays:

FIRST INCRMNT

then stops and displays:

C=
0.0000

Key in the first increment, then press R/S. The calculator briefly displays:

GENRL INCRMNT

then stops and displays:

D=
0.0000

Key in the increment to be used for all the other distances, then press R/S. The calculator then briefly displays:

RD VALUE

then stops and displays the running distance of the start point, such as follows:

U=
24,367.0000

Press R/S to continue. The calculator briefly displays:

HP-35s Calculator Program
Compute Values for a Parabolic Vertical Curve

Curves 2A

EL VALUE

then stops and displays the elevation at the start point, such as follows:

V=
103.4500

Press R/S to continue. The calculator then loops through the following sequence, briefly displaying:

RD VALUE

then stopping and displaying the next running distance value, such as follows:

X=
24,467.0000

Press R/S to continue. The calculator briefly displays:

EL VALUE

then stops and displays the elevation value at the running distance just given, such as follows:

H=
111.2000

Press R/S to continue through this loop until the increments extend past the last point. At this stage, the last point is displayed. The calculator briefly displays:

END POINT

then briefly displays:

RD VALUE

then stops and displays the running distance of the end point, such as follows:

X=
24,767.0000

Press R/S to continue. The calculator briefly displays:

EL VALUE

then stops and displays the elevation of the end point, such as follows:

H=
107.45

Press R/S to continue. The calculator briefly displays

PROGRAM END

HP-35s Calculator Program
Compute Values for a Parabolic Vertical Curve

and then stops at the end of the program, having reset Flag 10 to its value at the time the program was started.. If R/S is pressed again, the program returns to the point whence it was called. This is not strictly necessary, unless the program was called by another program.

Sample Computations

The sample computations are based on the following general data:

Running Distance of the Point of Intersection = 24,567.0000

Elevation of the Point of Intersection = 123.4500

Length of the Curve = 400.0000

The running distance of the start point is therefore 24,367 and of the end point is 24,767.

The following tabulations show the results for different in and out gradients. The increments used for the running distance values are both 50 (both the first increment and the general increment).

Case	In Grade	Out Grade	Start EL	End EL	Max/Min RD	Max/Min EL
1	0.0200	-0.0200	119.45	119.45	24567.00	121.45
2	0.0400	-0.0600	115.45	111.45	24527.00	118.65
3	0.0600	-0.0400	111.45	115.45	24607.00	118.65
4	0.0800	-0.1000	107.45	103.45	24544.78	114.56
5	0.1000	-0.0800	103.45	107.45	24589.22	114.56
6	-0.0200	0.0400	127.45	131.45	24500.33	126.12
7	-0.0400	0.0200	131.45	127.45	24633.67	126.12
8	-0.0600	0.0800	135.45	139.45	24538.43	130.31
9	-0.0800	0.1000	139.45	143.45	24544.78	132.34
10	-0.1000	0.0600	143.45	135.45	24617.00	130.95
11	0.0200	0.0400	119.45	131.45	23967.00	115.45
12	0.0400	0.0200	115.45	127.45	25167.00	131.45
13	0.0600	0.0800	111.45	139.45	23167.00	75.45
14	0.0800	0.1000	107.45	143.45	22767.00	43.45
15	0.1000	0.0600	103.45	135.45	25367.00	153.45
16	-0.0200	-0.0400	127.45	115.45	23967.00	131.45
17	-0.0400	-0.0600	131.45	111.45	23567.00	147.45
18	-0.0600	-0.0400	135.45	115.45	25567.00	99.45
19	-0.0800	-0.1000	139.45	103.45	22767.00	203.45
20	-0.1000	-0.0800	143.45	107.45	26367.00	43.45

HP-35s Calculator Program
Compute Values for a Parabolic Vertical Curve

Curves 2A

Case	Running Distance								
	24367	24417	24467	24517	24567	24617	24667	24717	24767
1	119.45	120.33	120.95	121.33	121.45	121.33	120.95	120.33	119.45
2	115.45	117.14	118.20	118.64	118.45	117.64	116.20	114.14	111.45
3	111.45	114.14	116.20	117.64	118.45	118.64	118.20	117.14	115.45
4	107.45	110.89	113.20	114.39	114.45	113.39	111.20	107.89	103.45
5	103.45	107.89	111.20	113.39	114.45	114.39	113.20	110.89	107.45
6	127.45	126.64	126.20	126.14	126.45	127.14	128.20	129.64	131.45
7	131.45	129.64	128.20	127.14	126.45	126.14	126.20	126.64	127.45
8	135.45	132.89	131.20	130.39	130.45	131.39	133.20	135.89	139.45
9	139.45	136.01	133.70	132.51	132.45	133.51	135.70	139.01	143.45
10	143.45	138.95	135.45	132.95	131.45	130.95	131.45	132.95	135.45
11	119.45	120.51	121.70	123.01	124.45	126.01	127.70	129.51	131.45
12	115.45	117.39	119.20	120.89	122.45	123.89	125.20	126.39	127.45
13	111.45	114.51	117.70	121.01	124.45	128.01	131.70	135.51	139.45
14	107.45	111.51	115.70	120.01	124.45	129.01	133.70	138.51	143.45
15	103.45	108.33	112.95	117.33	121.45	125.33	128.95	132.33	135.45
16	127.45	126.39	125.20	123.89	122.45	120.89	119.20	117.39	115.45
17	131.45	129.39	127.20	124.89	122.45	119.89	117.20	114.39	111.45
18	135.45	132.51	129.70	127.01	124.45	122.01	119.70	117.51	115.45
19	139.45	135.39	131.20	126.89	122.45	117.89	113.20	108.39	103.45
20	143.45	138.51	133.70	129.01	124.45	120.01	115.70	111.51	107.45

These values should allow the program to be tested to make sure it is working properly. The above tabulated values were calculated by spreadsheet, rather than the calculator, but the calculator results were checked against the these tabulations.

Storage Registers Used

- A** Difference between the incoming and outgoing gradients.
- B** Parameter a in the parabola equation.
- C** Elevation difference. First increment value for ‘stepping’ option.
- D** Running Distance of a computed point. General increment for ‘stepping’ option.
- E** Elevation of a computed point.
- F** Running Distance of a computed point.
- H** Elevation of a computed point, and entered elevation to have RD calculated.
- I** Distance along curve from start point.
- L** Length of the curve to be computed.
- P** Gradient of the incoming tangent (start grade)
- Q** Gradient of the outgoing tangent (end grade).

HP-35s Calculator Program
Compute Values for a Parabolic Vertical Curve

Curves 2A

- R** Running Distance of the Point of Intersection.
- S** Elevation of the Point of Intersection.
- U** Running Distance of the start point.
- V** Elevation of the start point.
- X** Running Distance entered to compute elevation at that point.
- Y** Yes/No variable for option choices.

Statistical Registers: Not used.

Labels Used

Label **P** Length = 1383 Checksum = 6E0F

Use the length (LN=) and Checksum (CK=) values to check if program was entered correctly.
Use the sample computation to check proper operation after entry.

Flags Used

Flags 1 and 10 are used by this program. Flag 10 is set for this program, so that equations can be shown as prompts. Flag 1 is used to record the setting of Flag 10 before the program begins. At the end of the program, Flag 10 is reset to its original value, based on the value in Flag 1.