7

Solve aplet

About the Solve aplet

The Solve aplet solves an equation or an expression for its *unknown variable*. You define an equation or expression in the symbolic view, then supply values for all the variables *except one* in the numeric view.

Note the differences between an equation and an expression:

- An *equation* contains an equals sign. Its solution is a value for the unknown variable that makes both sides have the same value.
- An *expression* does not contain an equals sign. Its solution is a *root*, that is, a value for the unknown variable that makes the expression have a value of zero.

You can use the Solve aplet to solve an equation for any one of its variables.

When the Solve aplet is started, it opens in the Solve symbolic view.

- In Symbolic view, you specify the expression or equation to solve. You can define up to ten equations (or expressions), named E0 through E9. Each equation can contain up to 27 real variables, named A through Z and θ.
- In Numeric view, you specify the values of the known variables, highlight the variable that you want to solve for, and press **SOLVE**.

You can solve the equation as many times as you want, using new values for the knowns and highlighting a different unknown.

Note: It is not possible to solve for more than one variable at once. Simultaneous linear equations, for example, should be solved using matrices or graphs in the Function aplet.

Getting started with the Solve aplet

The following example demonstrates how to solve an equation involving more than one variable. The problem to solve involves velocity and distance, as follows:

Find the acceleration needed to increase the speed of a car from 16.67 m/sec (60 kph) to 27.78 m/sec (100 kph) in a distance of 100 m.

The equation to solve is as follows:

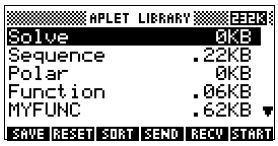
$$v^2 = u^2 + 2ad$$

Open the Solve aplet

1. Open the Solve aplet.

   APLET *Select* Solve **START**

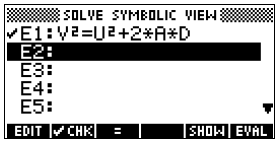
   The Solve aplet starts in the symbolic view.



Define the equation

2. Define the equation.

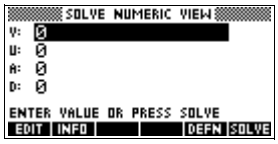
   ALPHA V X² = ALPHA U X² + 2 * ALPHA A * ALPHA D ENTER



Define known variables

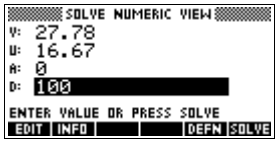
3. Define the known variables in the numeric view.

   NUM



4. Enter the values for the known variables.

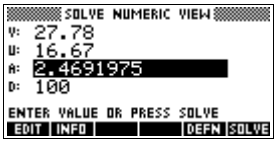
   2 7 . 7 8 ENTER
   1 6 . 6 7 ENTER
   ▼
   1 0 0 ENTER



Solve unknown variable

5. Solve for the unknown variable (A).

   ▼ ▼ **SOLVE**



   Therefore, the acceleration needed to increase the speed of a car from 16.67 m/sec (60 kph) to 27.78 m/sec (100 kph) in a distance of 100 m is 2.47 m/s^2.

   Because the variable A in the equation is linear once values are substituted into V, U and D, we know that we need not look for any other solutions.

Plot the equation

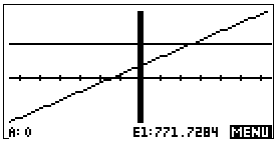
The Plot view shows one graph for each member of the selected equation. You can choose any of the variables in the Numeric view to be the independent variable.

The other variables take on the values assigned to them in the Numeric view. The current equation is $V^2 = U^2 + 2AD$. With the variable A highlighted, the Plot view will show two graphs.

One of these is $Y = V^2$, with V=27.78, or Y = 771.7284. This graph will be a horizontal line. The other graph will be $Y = U^2 + 2AD$, with U=16.67 and D=100, or Y = 200A + 277.8889. This graph is also a line. The desired solution is the value of A where these two lines intersect.

6. Plot the equation for variable A.

   VIEWS *Select* `Auto Scale`
   OK



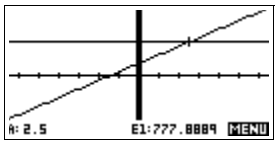
7. Trace along the graph representing the left member of the equation until the cursor nears the intersection.

   ▶ *~20 times*

8. Jump from the graph of the left member to the graph of the right member.

   ▼

   The Plot view provides a convenient way to find an approximation to a solution before using the Numeric view Solve option. See "Plotting to find guesses" on page 7-89 for more information.



Solve for the unknown variable

The Numeric view (NUM) in the Solve aplet is used to solve for an unknown variable. Known variables are defined in the numerical view to find an unknown variable. The Solve aplet can find only one unknown variable at a time. All of the variables must represent real values.

The unknown variable cannot be an index (as for a summation), limit (as for an integral), variable of integration or variable of differentiation.

1. The Solve aplet starts in the Symbolic View, where you can enter up to 10 expressions or equations for solving. *Note: You can use the* **=** *menu key to assist in the entry of equations.*
2. After you define and check one or more equations to solve, press NUM to display the Numeric view. This displays all the variables and their values, if any. For each variable except the unknown, type a number and press **OK**.
3. Move the highlight to the unknown's field and press **SOLVE**. The solution appears in the unknown's field.
4. You can repeat steps 2 and 3, substituting different values and selecting a different unknown each time.

Solve aplet's NUM view keys

Key	Meaning
EDIT	Copies the highlighted value to the edit line for editing. Press OK when done.

Key	Meaning
INFO	Displays a message about the solution (see "Interpreting Results," next page).
PAGE	Displays other pages of variables, if any.
DEFN	Displays the symbolic definition of the current expression. Press OK when done.
SOLVE	Finds a solution for the highlighted variable, based on the current value.
DEL	Clears highlighted variable to zero *or* deletes current character in edit line, if edit line was active.
SHIFT *CLEAR*	Resets all variable values to zero *or* clears the edit line, if cursor was in edit line.

Use an initial guess

You can usually obtain a faster and more accurate solution if you supply an estimated value for the unknown variable *before* pressing **SOLVE**. Solve starts looking for a solution at the initial guess.

An initial guess is especially important in the case of a curve that could have more than one solution. In this case, only the solution closest to the initial guess is returned.
Before plotting, make sure the independent variable is highlighted in the NUM view. Plot the equation to help you select an initial guess when you don't know the range in which to look for the solution

Number format

You can change the number format for the Solve aplet in the Numeric Setup view. The options are the same as in Home MODES: Standard, Fixed, Scientific, and Engineering. For the latter three, you also specify how many digits of accuracy you want. See "Mode settings" on page 1-16 for more information.

You might find it handy to set a different number format for the Solve aplet if, for example, you define equations to solve

for the value of money. A Number Format of Fixed 2 would be appropriate in this case to handle monetary values.

Interpreting results

After Solve has returned a solution, press **INFO** in the Numeric view for more information. You will see one of the following three messages. Press **OK** to clear the message.

Message	Condition
Zero	The Solve aplet found a point where the value of the equation (or the root of the expression) is zero within the calculator's 12-digit accuracy.
Sign Reversal	Solve found two points where the value of the equation has opposite signs, but it cannot find a point in between where the value is zero. This might be because *either* the two points are neighbours (they differ by one in the twelfth digit), *or* the equation is not real-valued between the two points. Solve returns the point where the value is closer to zero. If the value of the equation is a continuous real function, this point is Solve's best approximation of an actual root.
Extremum	Solve found a point where the value of the equation approximates a local minimum (for positive values) or maximum (for negative values). This point may or may not be a root. *Or:* Solve stopped searching at 9.9999999999E499, the largest number the calculator can represent

If Solve could not find a solution, you will see one of the following two messages.

Message	Condition
Bad Guess(es)	No solution found. One or more of the initial guesses lie outside the domain of the equation. Therefore, the solution was not a real number or it caused an error.
Constant?	No solution found. The value of the equation is the same at every point sampled.

It is important to check the information relating to the solve process. For example, for certain functions, the solution that the Solve aplet finds is not a solution, but the closest that the function gets to zero.

The Root-Finder at work

You can watch the process of the root-finder calculating and searching for a root. Immediately after pressing **SOLVE** to start the root-finder, press any key except ON. You will see two intermediate guesses and, to the left, the sign of the expression evaluated at each guess. For example:

+ 2 2.219330555745
- 1 21.31111111149

You can watch as the root-finder either finds a sign reversal or converges on a local minimum/maximum or does not converge at all. If there is no convergence in process, you might want to cancel the operation (press ON) and start over with a different initial guess.

Plotting to find guesses

The Plot view and the Plot Setup work as they do for the Function aplet, except that the PLOT may vary according to which variable is highlighted in the NUM view as the independent variable. The main reason for plotting in the Solve aplet is to help you find initial guesses and solutions for those equations that have difficult-to-find or multiple solutions.

Plotting the equation

A plot shows you graphically where the solution(s) must be:

- If you defined an expression, then the solution (root) is where the graph intersects the *x*-axis.
- If you defined an equation, then there are two graphs, one for each side of the equation. The solution is where the two graphs intersect. (If one side of the equation is constant, then one of the graphs will be a horizontal line.)

To plot an equation

1. Within the Solve aplet, define the equation to solve in the Symbolic view (SYMB).
2. If the equation uses trigonometric functions, set the angle measure in Symbolic Setup view (SHIFT *MODES*).
3. Enter the known variables in the Numeric view (NUM).
4. Highlight the variable to solve for in the Numeric view. The graph may vary according to which variable is highlighted and used as the independent variable.
5. Press VIEWS and select `Auto Scale` **OK** to plot the equation(s). Auto scaling usually gives you the best plot in Solve.

Example

Consider the equation of motion for an accelerating body:

$$x = v_0 t + \frac{at^2}{2}$$

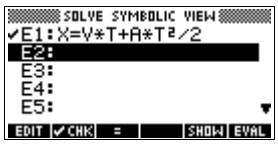
where x is distance, v_0 is initial velocity, t is time, and a is acceleration. This is actually *two* equations, $y = x$ and $y = v_0 t + (at^2) / 2$.

Since this equation is quadratic for t, there can be both a positive and a negative solution. However, we are concerned only with positive solutions, since only positive distance makes sense.

1. Select the Solve aplet and enter the equation.

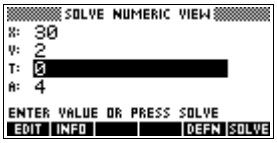
   APLET *Select* `Solve` **START**

   ALPHA X **=**
   ALPHA V * ALPHA T
   + (ALPHA A
   * ALPHA T X²) / 2
   OK



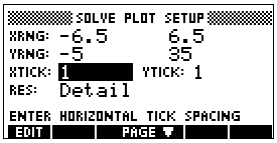
2. Find the solution for T (time) when X=30, V=2, and A=4. Enter the values for X, V, and A: then highlight the independent variable, T.

   NUM
   30 ENTER
   2 ENTER
   ▼ 4 ENTER
   ▼ ▼ *to highlight T*



3. Use the Plot view to find an initial guess for T. First set appropriate X and Y ranges in the Plot Setup. Since we have an equation, $X=V*T+A*T^2/2$, the plot will produce two graphs: one for Y=X and one for $Y=V*T+A*T^2/2$. Since we have set X=30 in this example, one of the graphs will be Y=30. Therefore, make the YRNG -5 to 35. Keep the XRNG default of -6.5 to 6.5.

   SHIFT *SETUP-PLOT*
   ▼ (-) 5 ENTER
   35 ENTER

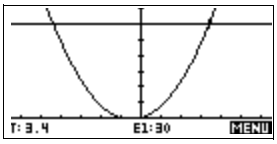


4. Plot the graph.

   PLOT

5. Move the cursor near the positive (right-side) intersection. This cursor value will be an initial guess for T.

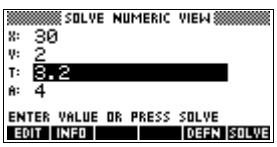
   ▶ *to move cursor to the intersection.*



   The two points of intersection show that there are two solutions for this equation. However, only positive values for *x* make sense, so we want to find the solution for the intersection on the right side of the *y*-axis.

6. Return to the Numeric view.

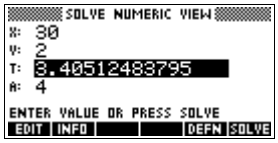
   NUM



Note: the T-value is filled in with the position of the cursor from the Plot view.

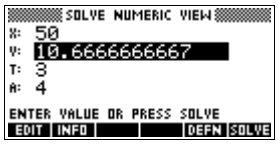
7. Ensure that the T value is highlighted, and solve the equation.

   SOLVE



8. Use this equation to solve for another variable, such as velocity. How fast must a body's initial velocity be in order for it to travel 50 m within 3 seconds? Assume the same acceleration, 4 m/s^2. *Leave the last value of V as an initial guess.*

   3 [ENTER] [▲] [▲] [▲]
   50 [ENTER]
   SOLVE



Using variables in equations

You can use any of the real variable names, A through Z and θ. Do not use variable names defined for other types, such as M1 (a matrix variable).

Home variables

All Home variables (other than those for aplet settings, like Xmin and Ytick) are *global*, which means they are *shared* throughout the different aplets of the calculator. A value that is assigned to a Home variable anywhere remains with that variable wherever its name is used.

Therefore, if you have defined a value for T (as in the above example) in another aplet or even another Solve equation, that value will show up in the Numeric view for this Solve equation. When you then redefine the value for T in this Solve equation, that value will apply to T in all other contexts (until it is changed again).

This sharing allows you to work on the same problem in different places (such as Home and Solve) without having to update the value everywhere whenever it is recalculated.

As the Solve application uses any existing variable values, be sure to check for existing variable values that may affect the solve process. (You can use SHIFT *DEL* to reset all values to zero in the Solve NUM view if you wish.)

Aplet variables

Functions defined in other aplets can also be referenced in the Solve aplet. For example, if, in the Function aplet, you define:
`F1(X)=X`^{2}`+10`
In the Solve aplet, you can enter
`F1(X)=50`
to solve the equation `X`^{2}`+10`=50.