TEXAS INSTRUMENTS

TI-89/TI-92 Plus/Voyage™ 200 Polynomial Root Finder

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What is the Polynomial Root Finder Application?

The Polynomial Root Finder application (App) calculates numeric roots (zeros) of polynomials using the calculator's eigenvalue routines.

The Polynomial Root Finder App provides a convenient, easy-to-use interface to simplify setting up the problem, solving it, and exploring the solution.
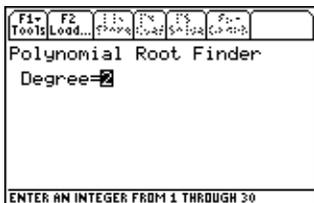
You can:

- Edit the coefficients of the polynomial.7

- Load a list for the coefficients.

- Store the solution in a list.

- Graph the polynomial.

- Solve up to 30th-order real or complex polynomials.

Entering a Problem

Entering data manually

1. [Start] the Polynomial Root Finder App and select **New**.

2. Enter the degree of the polynomial. The degree must be an integer between 1 and 30.

3. Press $\boxed{\text{ENTER}}$ to display the Coefficients screen.

4. Enter the first coefficient value. You can enter a real or complex value or an expression that resolves to a real or complex value.

5. Press $\boxed{\text{ENTER}}$ or $\odot$ to go to the next coefficient.

6. Continue entering coefficient values.

7. Press $\boxed{\text{ENTER}}$ after entering the last coefficient value.

Loading existing data

You can load an existing list as all or part of the problem from within the Polynomial Root Finder App by using either of the following methods.

- Press [F2] and select a folder and list.

- Press [F1] **1:Load Coefficients** and select a folder and list.

Editing coefficients

1. If you are on the Solutions screen, press [F4] to display the Coefficients screen.

2. Move the cursor to a coefficient and change its value.

3. Press [ENTER] to accept the changes.

Clearing coefficients

Press [F1] **8:Clear All**.

Starting a new problem

Press [F1] **3:New Problem**.

Solving Numerically

Solutions are always computed numerically, regardless of whether the Exact/Approx mode setting is **Auto**, **Exact**, or **Approximate**. The Polynomial Root Finder App calculates roots numerically by finding the eigenvalues of a corresponding companion matrix.

1. Complete the coefficient entry in the Coefficients screen. You must press ENTER to accept the last entered or changed value.

2. Press F5 to solve the problem. The numeric values of the roots appear in the Solutions screen. The busy indicator on the status line displays while calculating the solution.

> **Note** The roots $x_1 \ldots x_n$ are displayed according to the **Complex Format** mode setting. If the mode is **Real**, complex roots are displayed as **Non-Real** *unless* a complex coefficient was entered.

Solving Graphically

1. After entering coefficients, press [2nd] [F6] (TI-89) or [F6] **1:Open Graph**. This option is available from either the Coefficients or Solutions screen.

2. Select the graphing options and press [ENTER].

   - **Split Screen** — Choose **1:Full** or **2:Left-Right**. (The Top-Bottom option is not available.)

   - **Store Poly to** — Choose a **y**-variable or choose **1:none** to graph without storing.

   - **Zoom** — Choose **1:ZoomRoots**, **2:ZoomStd**, **3:ZoomFit**, or **4:none**. **ZoomRoots** sets the viewing window based on the solutions found by the Polynomial Root Finder App, relative minimums and maximums, and inflection points.
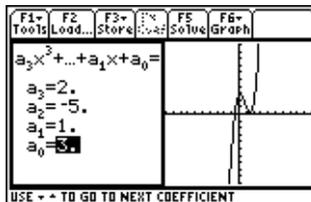
When the graph displays, the standard graph tools such as Zoom, Trace, and Math are available on the tool bar.

Displaying graph with coefficients or solutions

In split screen mode, a thick border indicates the active portion. Press [2nd] [⊞] to switch between the graph and the Coefficients or Solutions portion.
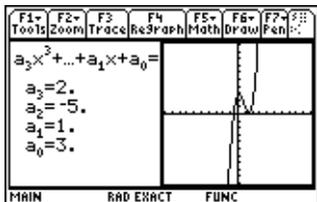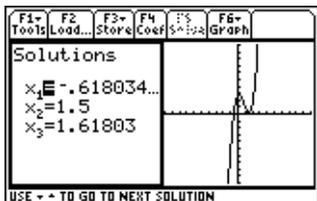

Graph portion is active

Coefficients portion is active

To display the Solutions screen with the graph, switch to the Coefficients portion of the split screen, and press [F5].

Solutions with graph

To return to the Coefficients screen, press [F4] from the Solutions screen.

While in split screen mode, you can change the coefficients and recalculate the solutions. The graph does not automatically update for the new values. To update the graph, select [2nd] [F6] (TI-89) or [F6] **1:Open Graph** from the Coefficients or Solutions screen.

Quitting the graph

1. Press [2nd] [⊞] to switch to the Coefficients or Solutions screen.

2. Press [2nd] [F6] (TI-89) or [F6] **2:Quit Graph**.

Storing

Once you have entered the coefficients, you can store:

- All the coefficients to a list.

- An individual coefficient to a variable.

- The polynomial to a Y= equation.

Once you have calculated the roots, you can store:

- All the roots to a list.

- An individual root to a variable.

To store from either the Coefficients or Solutions screen:

- Press [F3] and select one of the following:

  - **1:Coefficients** and select a folder and list name.

  - **2:Solutions** and select a folder and list name.

  - **3:Poly to Y= Editor** and select a y-variable.

To store individual coefficients or roots from the Coefficients or Solutions screen:

1. On the Coefficients screen, place the cursor on the value you want to store.

   On the Solutions screen, place the cursor on the equal sign (=) of the x_i value you want to store.

2. Press $\boxed{\text{STO►}}$.

3. Enter a variable name and press $\boxed{\text{ENTER}}$.

Navigating Within the Polynomial Root Finder App

- ⬆ ◊ or ⬆ ◊ highlights values on the Coefficients screen. Values can be cut, copied, and pasted.

- [2nd] ◊ or [2nd] ◊ moves the cursor to the beginning or end of a value on the Coefficients screen.

- [2nd] ⬠ or [2nd] ⬡ moves the cursor up or down one page on the Coefficients or Solutions screen.

- ⬥ ⬠ or ⬥ ⬡ moves the cursor to the first or last value or result on the Coefficients or Solutions screen.

- [2nd] [⬚] toggles between applications or between split screen portions.

Notes and Hints

- Radian angle mode is recommended for complex number calculations if the Complex Format mode setting is **Polar**. Internally, the TI-89 / TI-92 Plus / Voyage™ 200 PLT converts all entered trigonometry values to radians, but it does not convert values for exponential, logarithmic, or hyperbolic functions.

- The values of non-real roots are shown on the Solutions screen only if the Complex Format mode setting is **Rectangular** or **Polar**. If the format is Real, the Solutions screen displays **Non-Real**.

- 0 is not a valid entry for a_n. If you press $\boxed{\text{ENTER}}$ on any other coefficient without entering a value, 0 is entered automatically. If you press $\boxed{\text{ENTER}}$ on a_n without entering a value, 1 is entered automatically.

Example — Roots of a Third-Degree Polynomial

Find the roots of $2x^3 - 5x^2 + x + 3 = 0$.

1. Start the Polynomial Root Finder App and select **New**.

2. Press **3** $\boxed{\text{ENTER}}$ for a third-degree polynomial.

3. Enter the coefficients: a_3 = **2**, a_2 = **⁻5**, a_1 = **1**, a_0 = **3**.

4. Press $\boxed{\text{F5}}$ to solve the problem. The busy indicator on the status line displays while the solution is calculated.

   The values for x_1, x_2, and x_3 are displayed:

   x_1 = ⁻.618034
   x_2 = 1.5
   x_3 = 1.61803

Example — Complex Roots

Find the roots of $x^3 + x^2 + x + 1 = 0$.

1. Press MODE and set **Angle** to **Radian** and **Complex Format** to **Real**.

2. [Start] the Polynomial Root Finder App and select **New**.

3. Press **3** ENTER for a third-degree polynomial.

4. Enter the coefficients: $a_3 = $ **1**, $a_2 = $ **1**, $a_1 = $ **1**, $a_0 = $ **1**.

5. Press F5 to solve the problem. The busy indicator on the status line displays while the solution is calculated.

   The values for x_1, x_2, and x_3 are displayed:

   $x_1 = $ ⁻**1.**
   $x_2 = $ **Non-Real**
   $x_3 = $ **Non-Real**

Example — Complex Coefficients

Find the roots of $15x^3 - 4ix^2 + (7+i)x + 2i = 0$.

1. Press MODE and set **Angle** to **Radian** and **Complex Format** to **Rectangular**.

2. [Start] the Polynomial Root Finder App and select **New**.

3. Press **3** ENTER for a third-degree polynomial.

4. Enter the coefficients: a_3 = **15**, a_2 = **-4i**, a_1 = **7+i**, a_0 = **2i**.

5. Press F5 to solve the problem. The busy indicator on the status line displays while the solution is calculated.

   The values for x_1, x_2, and x_3 are displayed:

   x_1 = -.038274+.926765∗i
   x_2 = -.174161-.282031∗i
   x_3 = .212435-.378067∗i

Errors, Error Messages, and Restrictions

Message	What To Do
Highest degree polynomial coefficient cannot be zero.	You must enter a nonzero value for a_n.
All functions are in use. Clear unnecessary functions from the Y= Editor.	Press ◆ [Y=] and clear any unnecessary functions.
Memory	The Polynomial Root Finder App requires at least 3000 bytes of RAM to run properly. When the amount of available RAM falls below this threshold, the application may display an **Error: Memory** dialog box and return to the Home screen or simply exit to the Home screen. If this occurs, archive or delete some variables before returning to the application.

Installing the Polynomial Root Finder App

Detailed Flash application installation instructions are available from education.ti.com/guides.

You will need:

- A TI-89 / TI-92 Plus / Voyage™ 200 PLT with the latest Advanced Mathematics Software Operating System. Download a free copy from education.ti.com/softwareupdates.

- A computer using either Microsoft® Windows® or Apple® Macintosh® operating system software.

- A TI-GRAPH LINK™ computer-to-calculator cable, available for purchase from the TI Online Store.

- Either TI Connect™ software or TI-GRAPH LINK connectivity software for the TI-89 / TI-92 Plus. Download a free copy from education.ti.com/softwareupdates.

Starting and Quitting the Application

Starting the Polynomial Root Finder App

The instructions in this guidebook refer to this Flash application only. For help using this product, refer to the comprehensive guidebook at education.ti.com/guides.

1. Press APPS and select **Polynomial Root Finder**.

2. Select the problem type from the menu.

   - **Current** returns to the screen you were on when you left the Polynomial Root Finder App.

   - **Open** lets you select an existing list to use as the coefficients of the polynomial.

   - **New** creates a new problem.

Quitting the Polynomial Root Finder App

Press 2nd [QUIT] from any screen.

Deleting an Application

Deleting an application removes it from the handheld device and increases space for other applications. Before deleting an application, consider storing it on a computer for reinstallation later.

1. [Quit](#) the application.

2. Press [2nd] [VAR-LINK] to display the VAR-LINK [ALL] screen.

3. Press [2nd] [F7] (TI-89) or [F7] to display the list of installed applications.

4. Select the application you want to delete.

5. Press [F1] **1:Delete**. The VAR-LINK delete confirmation dialog box displays.

6. Press [ENTER] to delete the application.

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